ICTP South American Institute for Fundamental Research (ICTP-SAIFR)

Location: IFT-UNESP, Sao Paulo

Acting director: Nathan Berkovits
Acting vice-director: Rogerio Rosenfeld
Executive Secretary: Nadia Roque
Computer Systems Manager: Danilo Ramos
Financial Manager: Lilia Faria

Motivation

- Theoretical physics institutes play an important role in bringing researchers together and reducing the amount of bureaucracy involved in inviting visitors and organizing activities.
- There are dozens of such institutes in North America, Europe, and Asia in both developed and developing countries.
- South America has a few theoretical physics institutes in small cities (CECS in Valdivia, IIP in Natal), but they do not play the role of regional centers.

Why IFT-UNESP in Sao Paulo?

- IFT-UNESP is one of the oldest and most prestigious graduate schools in theoretical physics in South America.
- The Sao Paulo state research funding agency FAPESP is the most stable and well-funded agency in South America.
- IFT-UNESP is centrally located next to a major bus/train station near the largest South American airport and close to several large universities.

Connection with ICTP

- The ICTP in Trieste has supported theoretical physics in South America for over 45 years.
- In rapidly growing countries such as Brasil, the ICTP has decided to create regional ICTP centers which can help support less-developed countries of the region. Other regional ICTP centers are planned in Mexico and Turkey.
- In addition to providing organizational expertise, the ICTP in Trieste also provides funding for visitors to the center from other South American countries.

Short history of ICTP-SAIFR

March 2010 - ICTP management suggests opening of South American regional center at IFT-UNESP in Sao Paulo.

August 2010 - Rector of UNESP gives enthusiastic suport.

November 2010 - Memorandum of Understanding is signed between ICTP and UNESP.

June 2011 - First meeting of Steering Committee is held. Acting director and scientific council are appointed and 2012 activities are decided.

August 2011 - Three ICTP-SAIFR secretaries are hired.

September 2011 - International seach committee for first 2 permanent positions is formed.

November 2011 - 5-year budget is appoved by FAPESP.

February 2012 - Joint Steering Committee/Scientific Council meeting and Opening Ceremony are held.

ICTP SAIFR

International Centre for Theoretical Physics
South American Institute for Fundamental Research

Ceremony of Inauguration of ICTP-SAIFR on February 6, 2012

(left to right)

Carlos Brito Cruz (Fapesp scientific director)
Juan Maldacena (representing South America)
Fernando Quevedo (steering council chair and ICTP director)
Julio Cezar Durigan (UNESP rector)
Juan Montero (IFT director)
Jacob Palis (Brazil Academy of Science president)
Peter Goddard (scientific council chair and IAS ex-director)

Contributions to Budget

UNESP

5 permanent research professor positions

3 secretaries

Infrastructure of IFT-UNESP

FAPESP (5-year projeto tematico)

9 postdoctoral positions

180 months of visitors

2-week schools for PhD students

ICTP

Visitors from other South American countries

Councils

Steering committee

Fernando Quevedo (chair)-ICTP director
Julio Cezar Durigan - UNESP acting rector
Carlos Brito Cruz - FAPESP scientific director
Jacob Palis - Brazilian Academy of Science president
Juan Maldacena – representing South America

Scientific council

Peter Goddard (chair) – IAS, Princeton
Seifallah Randjbar-Daemi - ICTP vice-director
Juan Montero - IFT-UNESP director
Marcela Carena - Fermilab, Batavia
Marcel Clerc - Univ. de Chile, Santiago
Luiz Davidovich - UFRJ, Rio de Janeiro
Daniel Sudarsky - UNAM, Mexico City
Matias Zaldarriaga - IAS, Princeton
Anthony Zee - Univ. of California, Santa Barbara
Barton Zwiebach - MIT, Cambridge

2012 ICTP-SAIFR activities

São Paulo International Schools on Theoretical Physics

(2-week PhD schools on specific research topic)

- **Southern-Summer School on Mathematical Biology (Jan. 16-29)**
- **Advanced School in Relativistic Astrophysics and Cosmology (July 16-27)**
- **Symbolic Computation in Theoretical Physics: Integrability and super-Yang Mills (Nov. 5-16)**

Workshops

Perspectives on Non-Perturbative QCD (May 7-8)

Joint IIP-ICTP Workshop on Gravity and String Theory (May 8-9)

IX Simposio Latinoamericano de Fisica de Alta Energia - SILAFAE (Dec. 10-14)

Minicourses

Joseph Minahan on Integrability and AdS-CFT (Sept. 3-4)

Boris Kayser on Fundamental Issues in Particle Physics (Oct. 22-23)

Rafael Porto on Effective Field Theory (Nov. 28 – Dec. 5)

2013 ICTP-SAIFR activities

São Paulo International Schools on Theoretical Physics

- 2nd Southern-Summer School on Mathematical Biology (Jan. 21 – Feb. 2)
- School on Particle Physics in the LHC Era (April 1-12)
- School on Nonperturbative QCD (May 27-June 7)
- School on Approaches to Quantum Gravity (Sept. 2-9)
- School on Fundamental Astrophysics (Oct. 7-18)
- School on Nonlinear Optics and Nanophotonics (Nov. 25 – Dec. 6)

Workshops

VI Quantum Gravity in the Southern Cone (Sept. 11-13)

Workshop on Higher-Spin and Higher Curvature Gravity (Nov. 4-7)

Minicourses/Programs

Edward Corrigan on Classical and Quantum Integrability (April 15-17)

Kevin McAnn on Energetic Approach to Food Webs (June 17-21)

Riccardo Sturani on Gravitational Waves (August 1-29)

Celso Grebogi on Complex Systems (Sept. 23-24)

Pedro Vieira on Amplitudes/Correlation Functions (Oct. 20 - Dec. 20)

2014 ICTP-SAIFR activities

São Paulo International Schools on Theoretical Physics

- 3rd Southern-Summer School on Mathematical Biology (February)
- School on Random Matrices (August)
- School on Electronic Structure and Quantum Transport Methods (September)
- School on Observational Cosmology (November)

Workshops/Minicourses/Programs

Integrability and AdS-CFT

Particle Physics

Mathematical Biology

Cosmology

Participation in Activities

- All applications are online and are judged by the selection committee of the activity.
- Sao Paulo International Schools are two weeks with 4-6 lecturers and 50-60 PhD students. Travel and local expenses are paid for students from cities outside Sao Paulo. All lectures are recorded with ICTP equipment and put online.
- Workshops and minicourses are typically 2-5 days and local expenses are paid for participants.
- Programs are typically 3-4 weeks on selected topics with invited visitors.
- Proposals for activites can be submitted online and are judged in February of the preceding year.

Permanent Job Applications

Applications for permanent research professor positions are online and are evaluated by an international search committee. There is no application deadline and the search committee is currently evaluating applications. The first of the five positions was awarded to Eduardo Ponton in the area of particle physics, and the search for the second position is focusing on cosmology and related fields.

International Search Committee:

Peter Goddard (IAS) – committee chairman

Marcela Carena (Fermilab)

David Gross (KITP)

Leo Kadanoff (Chicago)

Martin Rees (Cambridge)

Uros Seljak (Berkeley)

Robert Wald (Chicago)

Simon White (MPA)

Edward Witten (IAS)

Matias Zaldarriaga (IAS)

Postdoctors and visitors

- Applications for postdocs and for short-term and long-term visits are online. There is no application deadline, and several postdoctoral positions are currently available.

- The ICTP-SAIFR has signed visiting agreements with Perimeter Institute, the CERN and Fermilab theory groups, and Nordita which allows ICTP-SAIFR members to visit these institutions and vice versa.

- Approximately 70 Associated Members from countries in South America will have standing invitations to visit and will help to advertise ICTP-SAIFR activities.

More Information

- Scientific bulletins on ICTP-SAIFR activities are sent by email every three months to our email mailing list.

- Posters for ICTP-SAIFR schools and workshops are sent to over 500 universities around the world.

- All activity information and online applications are on our webpage

www.ictp-saifr.org

New Results in the Pure Spinor Formalism of the Superstring

Pure Spinor Superstring

- D=10 Green-Schwarz-Siegel matter variables

$$x^m, \theta^\alpha, p_\alpha$$

- Pure spinor ghost variables λ^α, w_α

  satisfying the constraint $\lambda\gamma^m\lambda = 0$

- Quadratic worldsheet action

$$S = \int d^2z(\partial x^m \bar{\partial} x_m + p_\alpha \bar{\partial}\theta^\alpha + w_\alpha \bar{\partial}\lambda^\alpha)$$

- No conformal anomaly (10 – 32 + 22 = 0) and correct Lorentz current anomaly (1 = 4 – 3)

$$\psi_m\psi_n \rightarrow \frac{1}{2}(p\gamma_{mn}\theta) + \frac{1}{2}(w\gamma_{mn}\lambda)$$

- Physical states are determined by cohomology of the nilpotent BRST operator

$$Q = \int dz \lambda^\alpha d_\alpha$$

where $d_\alpha = p_\alpha + \frac{1}{2}(\gamma_m \theta)_\alpha \partial x^m + \frac{1}{8}(\theta \gamma^m \partial \theta)$

is the worldsheet version of the spacetime supersymmetric derivative $D_\alpha = \frac{\partial}{\partial \theta^\alpha} + \frac{1}{2}(\gamma_m \theta)_\alpha \frac{\partial}{\partial x_m}$

- Although $\{D_\alpha, D_\beta\} = \gamma^m_{\alpha\beta} P_m$,

Q is nilpotent because of the pure spinor constraint $\lambda \gamma^m \lambda = 0$

Advantages over other formalisms

- Unlike in RNS formalism, formalism has manifest D=10 spacetime supersymmetry. Ramond and Neveu-Schwarz states are treated equally.
- All worldsheet variables have integer conformal weight and there is no sum over 2^{2g} spin structures on genus g surface.

- Unlike in GS formalism, covariant worldsheet action is quadratic and quantization is straightforward.
- Kappa symmetry is replaced with BRST invariance.

Two Recent Applications

- Computation of low-energy contribution to four-point 3-loop multiloop superstring amplitude (H. Gomez and C. Mafra, arXiv: 1308.6567)
- Construction of massless superstring vertex operators in $AdS_5 \times S^5$ Ramond-Ramond background using harmonic superspace (NB and T. Fleury, arXiv:1212.3296)

4-point 3-loop superstring amplitude (H. Gomez and C. Mafra)

- S-duality predicts the form of certain terms in the Type IIB low-energy effective action (Green and Vanhove, 2006)

$$S_{10} = \int d^{10}x\sqrt{g}[f_0(\phi)R + f_1(\phi)R^4 + f_2(\phi)\partial^4 R^4 + f_3(\phi)\partial^6 R^4 + ...]$$

where

$$f_0(\phi) = e^{-2\phi},$$
$$f_1(\phi) = 2\zeta_3 e^{-2\phi} + \frac{2\pi^2}{3},$$
$$f_2(\phi) = 2\zeta_5 e^{-2\phi} + \frac{8}{3}\zeta_4 e^{2\phi},$$
$$f_3(\phi) = 4\zeta_3^2 e^{-2\phi} + 8\zeta_2\zeta_3 + \frac{48}{5}\zeta_2^2 e^{2\phi} + \frac{8}{9}\zeta_6 e^{4\phi}.$$

- Coefficient of one-loop R^4 term computed by Sakai and Tanii (1987) using RNS formalism.
- Coefficient of two-loop $\partial^4 R^4$ term using RNS formalism shown to agree with unitarity by D'Hoker, Gutperle, Phong (2005). Explicit computation not possible because of unknown normalization of chiral determinants.
- Coefficient of one-loop R^4 term computed by Gomez (2009) using pure spinor formalism.
- Coefficient of two-loop $\partial^4 R^4$ computed by Gomez and Mafra (2010) using pure spinor formalism.

- No three-loop amplitude has previously been computed using any superstring formalism
- For general three-loop amplitude, computation is difficult in pure spinor formalism because of need for complicated regulator.
- But for F-terms such as $\partial^6 R^4$, do not need complicated regulator (NB, 2007) and easy to prove non-renormalization theorems.
- Gomez and Mafra (2013) computed the coefficient of this term and showed agreement with S-duality prediction assuming a certain Z_3 symmetry of genus-3 surfaces.

$AdS_5 \times S^5$ Vertex Operators

- Since $AdS_5 \times S^5$ background involves Ramond-Ramond fields, need to use GS or pure spinor formalism.
- Unknown how to describe unintegrated vertex operators in GS formalism since do not understand worldsheet ghosts.
- In pure spinor formalism, Type IIB unintegrated massless vertex operator is

$$V = \lambda^\alpha \hat{\lambda}^\beta A_{\alpha\beta}(x, \theta, \hat{\theta})$$

- To be physical, V must satisfy QV=0 where

  $$Q = \lambda^\alpha D_\alpha + \hat{\lambda}^\beta \hat{D}_\beta$$

  and $D_\alpha \quad \text{and} \quad \hat{D}_\beta$ are the N=2 D=10 spacetime supersymmetric derivatives. In the $AdS_5 \times S^5$ background, Q acts geometrically by right-multiplication on a supercoset

  $$g(x,\theta,\hat{\theta}) \longrightarrow g(x,\theta,\hat{\theta})(\lambda^\alpha T_\alpha + \hat{\lambda}^\beta \hat{T}_\beta)$$

  where $g(x,\theta,\hat{\theta})$ takes values in $\frac{PSU(2,2|4)}{SO(4,1)\times SO(5)}$

- Supergravity vertex operators are dual to half-BPS super-Yang-Mills operators which are naturally expressed in N=4 d=4 harmonic superspace (P. Heslop and P. Howe, 2000)

- To express $V = \lambda^\alpha \hat{\lambda}^\beta A_{\alpha\beta}(x, \theta, \hat{\theta})$ in harmonic superspace, expand Q near the boundary of $AdS_5 \times S^5$ in terms of N=4 d=4 harmonic superspace variables and explicitly solve for QV =0.
- Can explicitly express V near the boundary in terms of harmonic superfields which are dual to the half-BPS super-Yang-Mills operators $Tr(W^n)$ in harmonic superspace
- Work is in progress on computing superstring amplitudes using these vertex operators