Scientific Report

Dark Matter and Particle Physics

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Supervisor: Nathan Berkovits
FAPESP Process: 2013/01792-8
01/10/2013 to 30/09/2016

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

Scientific report 2014

Nicolás Bernal
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I joined the ICTP-SAIFR last year; my contract started on October 1st 2013.

• **Conferences, Workshops & Seminars**
This year I have attended and presented my work in different international scientific events. On one hand, I presented my work about the 'Systematic uncertainties from halo asphericity in dark matter (DM) searches' in several international conferences: X Simposio Latinoamericano de Física de Altas Energías SILAFAE (December 23-28) in Medellín - Colombia, XXXV Encontro Nacional de Física de Partículas e Campos (September 15-19) in Caxambu - Brazil, Astroparticle Physics 2014 (June 23-28) in Amsterdam - Netherlands, PLANCK 2014 (May 26-30) in Paris - France and Mini Workshop on Cosmology (February 20-21) at the ICTP - SAIFR in São Paulo - Brazil.
On the other hand, I have also been invited to present my research on '$\mathbb{Z}_3$ DM and Goldstone bosons' and visit different research institutes like: Departamento de Raios Cósmicos e Cronologia, Universidade Estadual de Campinas (September 2) in Campinas - Brazil, Physikalisches Institut of the Universität Bonn (July 18) in Bonn - Germany and the Centro de Física Teórica de Partículas, Instituto Superior Técnico (June 3) in Lisboa - Portugal.
In addition I also played an active role in the local journal clubs taking place in São Paulo. On September 25th in the Joint USP/UNESP Journal Club I presented an article about the 'Baryon asymmetry of the universe from DM annihilations', on March 10th in the Astrophysics & Cosmology Journal Club (AC♮JC) I discussed the paper 'Discovering DM with gamma-rays from the galactic center' and on March 6th I talked about 'SIMP DM' in the Particle Physics Journal Club.

• **Astrophysics & Cosmology Journal Club (AC♮JC)**
Together with Saeed Mirshekari we organize a journal club devoted to subjects related to cosmology and astrophysics. It has been scheduled every two weeks on Mondays 11:00 am in the room #1 of the ICTP-SAIFR. We had national and international invited speakers like: Rita Bernabei (Università e INFN Roma Tor Vergata), Loïc Le Tiran (IAG - USP), Manuela Vecchi (USP - São Carlos), Ernany Schmitz (IFT - UNESP), Enrique Gaztañaga (Instituto de Ciencias del Espacio - Barcelona), Raul Abramo (IF - USP), Eduardo Pontón (ICTP - SAIFR), Riccardo Sturani (IFT - UNESP), Leandro Beraldo (IF - USP), Saeed Mirshekari (ICTP - SAIFR), Irène Balmès (IF - USP), Fabien Lacasa (ICTP - SAIFR), Nicolás Bernal (ICTP - SAIFR) and Morgan Le Delliou (IFT - UNESP). The (AC♮JC) has been well received and has been attended by people from both the UNESP (ICTP + IFT) and the USP (IAG + IF). It will continue during the next semester.

• **Publication**
In collaboration with Jaime E. Forero-Romero (Andes U., Bogotá), Raghuveer Garani (Bonn U.) and Sergio Palomares-Ruiz (Valencia U., IFIC), I wrote and article that got accepted in JCAP: *JCAP 1409 (2014) 004*. The title is: 'Systematic uncertainties from

halo asphericity in DM searches'. Abstract: Although commonly assumed to be spherical, DM halos are predicted to be non-spherical by N-body simulations and their asphericity has a potential impact on the systematic uncertainties in DM searches. The evaluation of these uncertainties is the main aim of this work, where we study the impact of aspherical DM density distributions in Milky-Way-like halos on direct and indirect searches. Using data from the large N-body cosmological simulation Bolshoi, we perform a statistical analysis and quantify the systematic uncertainties on the determination of local DM density and the so-called J factors for DM annihilations and decays from the galactic center. We find that, due to our ignorance about the extent of the non-sphericity of the Milky Way DM halo, systematic uncertainties can be as large as 35%, within the 95% most probable region, for a spherically averaged value for the local density of 0.3-0.4 GeV/cm^3. Similarly, systematic uncertainties on the J factors evaluated around the galactic center can be as large as 10% and 15%, within the 95% most probable region, for DM annihilations and decays, respectively.

• **Research plans for the year 2015**

Currently with Camilo García-Cely (Université Libre de Bruxelles, Belgium) and Rogério Rosenfeld (IFT - UNESP) we are studying the phenomenology of a model of scalar DM with a global $U(1)$ symmetry that spontaneously breaks into a $\mathbb{Z}_3$. This scenario has a very rich phenomenology that contains for example the possibility of explaining the extra relativistic degrees of freedom (dark radiation) that could be in the Planck data, and the possibility of solving some problems at small scales in the ΛCDM model like the 'missing satellites', the 'core versus cusp' and the 'too big to fail'. On top of that, in this model the generation of the DM relic abundance can happen via different mechanisms, namely self-annihilation, semi-annihilation and the very recently proposed $3 \to 2$ annihilation: '$\mathbb{Z}_3$ DM from a global $U(1)$ breaking, dark radiation and the SIMP scenario'.

Additionally with Camilo García-Cely and Thomas Hambye (Université Libre de Bruxelles, Belgium) we are studying the generation of the DM relic density in the Hidden Vector DM model. DM could be made of massive gauge bosons whose stability doesn't require to impose by hand any discrete or global symmetry. Stability of gauge bosons can be guaranteed by the custodial symmetry associated to the gauge symmetry and particle content of the model. The hidden sector interacts with the Standard Model particles through the Higgs portal quartic scalar interaction in such a way that the gauge bosons behave as thermal WIMPs. This can lead easily to the observed DM relic density in agreement with the other various constraints. We are examining regions of the parameter space that were previously excluded by the DM abundance but that are now reopened via new DM generation mechanisms.

A third project that has to be finished during 2015 is with Tracy Slatyer (MIT, USA). We are looking for the asymmetries in the possible triaxiality of the Milky Way DM halo. We are comparing the quadrant-based asymmetry for our various DM halo profiles with the astrophysical backgrounds and the maps of the gamma-ray emission from the diffuse model and the point sources measured by the Fermi satellite.

In recent years, a possible connection between the abundances of baryons and DM has been explored. Even if so far most of the studies have been in the context of the so-called asymmetric DM, a very different mechanism, dubbed 'WIMPy baryogenesis', has been recently proposed to relate the baryon asymmetry to (symmetric) DM annihilation. In both cases the DM candidate is a usual WIMP, thermally produced, with mass and interactions at the weak scale. However, there are alternate mechanisms of DM genesis involving Feebly Interacting Massive Particles (FIMPs), interacting so feeble with the thermal bath that they never attain thermal equilibrium. With some collaborators we already have studied realizations of the WIMPy baryogenesis and we are pursuing the research now focusing in the possibilities of generating simultaneously the observed baryon asymmetry of the universe and the measured FIMP DM relic abundance.

Em novembro de 2012, as vagas de pos-doutor foram divulgadas em SPIRES e em FAPESP Oportunidades nas paginas

http://inspirehep.net/record/1197828 e
http://www.fapesp.br/oportunidades/381

Também enviamos cartazes para 500 institutos internacionais com a divulgação das vagas, e colocamos um anuncio em Naturejobs (doi:10.1038/nj0389, published online 12 September 2012).

Recebemos mais que 200 aplicações que foram avaliadas pelo Conselho Cientifico do ICTP-SAIFR e pelos professores interessados do IFT-UNESP. Os candidatos com as melhores avaliações receberam uma oferta do Diretor do ICTP-SAIFR.

Scientific Report

Theory of elementary particles beyond the standard model

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FAPESP Process: 2012/22639-0
01/04/2013 to 31/03/2016

ICTP-SAIFR / IFT-UNESP
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2014

Research Report 2014

Gero von Gersdorff

Introduction

After completion of the first run of the LHC, we have started to probe physics responsible for electroweak symmetry breaking. The electroweak scale is many orders of magnitude lower than the Planck scale or the scale of a grand unified theory. For this reason, it is widely expected that new physics has to be present somewhere above the mass scale of the W and Z bosons. On the other hand, precision measurements at LEP have shown that the Standard Model (SM) accounts extremely well for all physics up to energies at least ten times the W mass, providing strict bounds and constraints, and setting the scale of new physics around the Teraelectronvolt (TeV). It is thus a very challenging task to build actual models which explain the low scale of electroweak symmetry breaking (EWSB)el without the necessity of severe fine tuning of parameters.

In 2012, the ATLAS and CMS experiments have announced the discovery of a new boson of mass ~ 125 GeV with properties consistent with the SM Higgs boson. The nature of the Higgs sector gives an excellent window to new physics, as almost all scenarios beyond the SM predict somewhat different Higgs couplings than the SM.

Research in 2014

Since the last report in December 2013, I have worked on the following projects.

New physics from light-by-light scattering at the LHC [1, 2].

Indirect probes of New Physics can be powerful if the SM process is strongly suppressed. This happens in scattering of light by light, which in the SM can occur via loops of quarks, leptons and the W boson. Due to the smallness of the electroweak coupling it is strongly suppressed. New Physics contributions can arise in two different ways, either from charged particles, or from neutral ones with couplings to the field strength tensor. In the former case, strong enhancements can occur in New Physics scenarios with very large electric charges. The effect is largely model-independent, as it only depends on the electric charges of the new particles and their spin, whereas other couplings/details of the model do not matter at all.

Light-by-light scattering can be measured at the LHC via so-called diffractive processes, in which the protons emit (almost) on-shell photons of energies in the range 200-1000 GeV. The scattered protons remain intact and can be detected in specially designed detectors installed close to the beam pipe in the forward region of the Atlas and CMS central detectors. This allows a precision measurement of the kinematics of the event, which in turn offers a very efficient way to reject backgrounds.

We have performed a detailed study of the sensitivity to the presence of new charged and neutral particles. We find that these experiments will be able to place model-independent bounds on charged particles that are more stringent than with other precision measurements, including the $g-2$ measurement of the muon. Morover neutral particles of spin 0 and 2 (such as dilaton and the Kaluza Klein graviton) can be excluded in the multi TeV range, if sufficiently strongly coupled.

Radiative corrections from higher spin fields [3]

It is known that contributions from charged particles in loops grow quite fast with the spin, as has been shown in the case of $s \leq 1$. If this behaviour remains true for larger spin, light-by-light scattering might constitute an interesting probe for the presence of higher-spin particles, like string excitations or strongly-interacting bound states. Further tools are however necessary to handle quantum computations involving higher-spin particles. We are in the process of developing a formalism to deal with loops of particles of spin ≥ 2.

A pseudo Nambu-Goldstone Higgs boson from Nambu-Jona-Lasinio symmetry breaking. [4]

The Higgs as a composite Goldstone boson is one of the prime candidates for a natural mechanism of EWSB. However, the dynamics of the global symmetry that gives rise to these Goldstone bosons has not been studied in detail. It has been known for a long time that a symmetry can be broken in a purely fermionic theory in the presence of a sufficiently strong four-fermion interaction. We apply this so-called Nambu-Jona-Lasinio (NJL) model to the breaking of the $SO(5)$ symmetry of typical composite Higgs models. The NJL model is extremely predicitive, as the low energy couplings of the emerging composite scalars are determined by a characteristic fixed-point behaviour of the renormalization group. In the context of the composite Higgs model, this results in highly predicted spectrum of resonances of spin 0, 1/2 and 1, which can be tested at the LHC.

Conferences and Seminars

I have presented my work at the following conferences and seminars.

- March 2014, Workshop: Hunting for a non standard Higgs sector, Benasque, Spain (invited plenary speaker)
- May 2014, Planck conference, Paris, France (invited plenary speaker)
- September 2014, BUSSTEPP summer school, University of Southampton, UK (invited lecturer)
- September 2014, University of Helsinki, Finland (invited seminar)
- November 2014, SILAFAE conference, Medellin, Colombia

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[3] S. Fichet and G. von Gersdorff, in preparation

[4] G. von Gersdorff, E. Pontin and R. Rosenfeld, in preparation

As vagas foram divulgadas em SPIRES, Physics Today e FAPESP Oportunidades.
As paginas são

http://careers.physicstoday.org/jobs#/detail/458430

http://www.slac.stanford.edu/spires/jobs/ads/96750.shtml
http://www.fapesp.br/oportunidades/310

Recebemos mais que 200 aplicacoes que foram enviadas para o steering committee e conselho cientifico do ICTP-SAIFR e também para professores interessados do IFT-UNESP para receber comentários e avaliações. Os candidatos com as melhores avaliações receberam ofertas do Diretor do ICTP-SAIFR.

Scientific Report

Ads-CFT Correspondence

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FAPESP Process: 2012/00756-5
01/10/2012 to 30/09/2015

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

Scientific report for 2013-2014

Chrysostomos Kalousios

Quantization of AdS×S particle in static gauge

In this paper we quantized the AdS×S particle dynamics in static gauge. We used the quantization scheme of [1] based on a covariant construction of the energy square operator in the coordinate representation, where the wave functions depend only on spatial coordinates. Let us first outline the scheme, which we present here in a slightly modified form.

Particle dynamics in a spacetime with coordinates x^μ, $\mu = (0, 1, ..., \mathcal{N})$ and a metric tensor $g_{\mu\nu}(x)$ can be described by the following action in the first order formalism

$$S = \int d\tau \Big(p_\mu \, \dot{x}^\mu - \frac{\lambda}{2} \left(g^{\mu\nu} p_\mu p_\nu + \mathcal{M}^2 \right) \Big) \ . \tag{1}$$

Here $\mathcal{M}$ is the particle mass, λ is a Lagrange multiplier and its variation provides the mass-shell condition

$$g^{\mu\nu} p_\mu p_\nu + \mathcal{M}^2 = 0 \ . \tag{2}$$

Using the Faddeev-Jackiw reduction [2] in the gauge

$$x^0 + p_0 \tau = 0 \ , \tag{3}$$

from (1) we get an ordinary Hamiltonian system[1]

$$S = \int d\tau \Big(p_n \, \dot{x}^n - \frac{1}{2} \, p_0^2 \Big) \ , \tag{4}$$

where p_0^2, as a function of the spatial coordinates and momenta (x^n, p_n) $(n = 1, ..., \mathcal{N})$, is obtained from the constraint (2) and the gauge fixing condition (3).

Notice that here we have modified the form of the standard static gauge $x^0 = \tau$ used in [1]. However, this modification does not change the quantization scheme and it appears more convenient for a Hamiltonian treatment of (4) in a static spacetime, as well as for the generalization to string theory [3].

A static spacetime metric tensor can be represented in the form

$$g_{\mu\nu} = \begin{pmatrix} g_{00} & 0 \\ 0 & g_{mn} \end{pmatrix} \ , \tag{5}$$

where g_{00} and g_{mn} are functions only of the spatial coordinates x^n. In this case the particle energy $E(p, x) = -p_0 > 0$ is conserved and from (2) follows that

$$E^2 = \Lambda(x) \, g^{mn}(x) \ p_m p_n + \mathcal{M}^2 \, \Lambda(x) \ , \tag{6}$$

with $\Lambda(x) := -g_{00}(x) > 0$.

Thus, the Hamiltonian in (4) corresponds to a motion of a particle in the potential field $V(x) = \frac{1}{2} \mathcal{M}^2 \Lambda(x)$ and in a curved background with metric tensor

$$h_{mn}(x) = \frac{1}{\Lambda(x)} \ g_{mn}(x) \ . \tag{7}$$

It is natural to quantize this system in the coordinate representation, where the wave functions $\psi(x)$ form a Hilbert space with covariant scalar product

$$\langle \psi_2 | \psi_1 \rangle = \int d^{\mathcal{N}} x \, \sqrt{h(x)} \ \psi_2^*(x) \, \psi_1(x) \ , \qquad h(x) := \det h_{mn}(x) \ . \tag{8}$$

[1] We neglect the total derivative term $-\frac{\mathrm{d}}{\mathrm{d}\tau} \left(\frac{1}{2} \, p_0^2 \tau \right)$.

On the basis of DeWitt's construction for quadratic in momenta operators [4], it was argued in [1] that the energy square operator is given by

$$E^2 = -\Delta_h + \frac{\mathcal{N}-1}{4\mathcal{N}}\,\mathcal{R}_h(x) + \mathcal{M}^2\,\Lambda(x)\ . \tag{9}$$

Here Δ_h is the covariant Laplace-Beltrami operator for the metric tensor h_{mn} and $\mathcal{R}_h(x)$ denotes the corresponding scalar curvature. The solution of the eigenvalue problem for (9) then provides the energy operator in diagonal form.

The coefficient in front of the scalar curvature term has been a subject of discussions during decades (see [5] and references therein). Therefore it is useful to comment on the value of this coefficient, $\frac{\mathcal{N}-1}{4\mathcal{N}}$, chosen in (9).

For the particle dynamics in $\mathrm{AdS}_{\mathcal{N}+1}$ this coefficient was calculated in [1] from the commutation relations of the symmetry generators. In this case $\mathcal{R}_h(x)$ corresponds to the curvature of a semi-sphere and, therefore, it is constant. The obtained constant shift in the energy square operator provides its spectrum in the form $(E_0+n)^2$, with fixed E_0 and a non-negative integer n, that leads to the correct energy spectrum for the AdS particle.

For a generic $\mathcal{N}+1$ dimensional static spacetime the same value of the coefficient $\frac{\mathcal{N}-1}{4\mathcal{N}}$ follows from the equivalence between the static gauge quantization and the covariant quantization based on the Klein-Gordon type equation.

The covariant quantization is a more conventional approach to the particle dynamics in AdS backgrounds [6, 7]. The general case with arbitrary dimensions and radii in this approach was analyzed in [8] from the perspective of scalar field propagators (see also [9]).

An interesting alternative quantization scheme based on the twistor and BRST formalisms was proposed in [10] for a massive bosonic particle in AdS_5. The obtained twistor construction was related to the oscillator construction of [11].

The quantization of a superparticle in the $\mathrm{AdS}_5\times\mathrm{S}^5$ background was done in [12], using the lightcone gauge and the technique developed in [13] (see also [14], which is based on a different lightcone type gauge).

The dynamics of a massive bosonic particle in $\mathrm{AdS}_5\times\mathrm{S}^5$ was considered in [15]. The authors used gauge invariant approach[2] and Dirac brackets formalism. The obtained results were applied for the analysis of string energy spectrum at large coupling in the context of the AdS/CFT correspondence.

The main motivation of most of papers on particles dynamics in the AdS spaces is to develop useful methods for the quantization of strings in these backgrounds.

Our motivation is the same and in this paper we aim to apply the static gauge quantization to $\mathrm{AdS}_{N+1}\times\mathrm{S}^M$ particle. AdS_{N+1} will be realized as a hyperbola $X^A\,X_A=-R^2$, with $A=(0',0,1,...,N)$, embedded in $\mathbb{R}^{2,\,N}$ and S^M as a M-dimensional sphere $Y_I\,Y_I=R_S^2$ in $\mathbb{R}^{M+1}$, with $I=(1,...,M+1)$.

Generating String Solutions in BTZ

Classical solutions of strings moving in $AdS_5\times S^5$ backgrounds have played an important role in the AdS/CFT correspondence. Spinning strings in AdS or the sphere have been established as excitations dual to operators with large spins or R-charges respectively [16]. These solutions were crucial in discovering the role of integrability and verifying many of its predictions in the AdS/CFT correspondence, see [17] for a review and a comprehensive list of references. Conversely integrability of strings in AdS was used to generate many new and useful solutions dual to single trace operators as well as Wilson loops in the field theory dual [18, 19, 20, 21].

The $AdS_3\times S^3$ dual pair is another example where the role of integrability is beginning to be investigated [22, 23, 24, 25, 26, 27, 28, 29]. One of the most interesting aspects of this dual pair is that classical string propagation in the background of AdS_3 black holes is integrable unlike the higher dimensional examples [30]. Integrability can be used to classify and generate new classical string solutions in the BTZ background. This in turn will shed light on aspects of black hole physics which can be probed

[2] Other references on gauge invariant quantization of the AdS particle dynamics one can find in [1].

by extended objects. In this paper we apply the dressing method introduced in the AdS/CFT context by [18], to generate and study new solutions of classical strings in the BTZ background.

Trajectories of point like objects described by geodesics are the canonical probes of the causal structure of the black hole. Space like geodesics in black hole backgrounds are used to obtain semi-classical limits of two point correlators in the boundary [31, 32, 33, 34, 35] and to study entanglement entropy of the boundary theory for 3 dimensional backgrounds [36]. Studying the behaviour of extended objects gives access to new phenomena near black hole horizons. For instance general arguments indicate that strings are expected to spread and become tensionless near black hole horizons due to quantum fluctuations [37, 38, 39]. Furthermore minimal surfaces whose boundary are pinned at asymptotic infinity are dual to Wilson/Polyakov loops [40, 41] and are useful probes of the transition from thermal AdS to a black hole in AdS [41, 42] They are also used to evaluate entanglement entropy [36]. See [43] for a nice review and also for some interesting properties of these minimal surfaces. Finally studying spinning strings in the background of black holes in AdS provides clues of the spectrum of the excitations in the dual thermal CFT analogous to the information provided by the spectrum of quasi-normal modes of fields in the black hole background.

The simplest kind of classical string solutions are those which are circular and which wind around the horizon and which then eventually fall into the horizon. Such solutions in the context of the BTZ black holes were studied in [24]. They were classified in terms of the finite gap solutions of the BTZ sigma model. However since the BTZ sigma model is integrable it is possible to apply the dressing method to construct more general classical solutions given a seed solution. In this paper we show how the dressing method developed for the $SU(1,1)$ principal chiral model [20, 21] can be used to generate classical string solutions for the sigma model on BTZ$\times S^1$. One of the by-products of this study is the proof that the dressing method preserves the Virasoro constraints of the seed solution. This method of generating solutions for the sigma model is different from that obtained by the spectral flow method used to obtain long strings in the $SL(2,R)$ WZW model in [44]. The Wess-Zumino term which allowed for the possibility of obtaining new solutions using the spectral flow in the $SL(2,R)$ WZW model is not present in the sigma model on BTZ$\times S^1$ considered in this paper.

We first apply the dressing method on time like geodesics to obtain classical string configurations. We obtain open string configurations which are pinned at the boundary but cross the horizon. The end points of these strings move on time like geodesics which have the same constants of motion as the seed geodesic but different initial condition. After a suitable regularization of the energy E and spin S of these solutions which involves subtracting the energy and spin density of seed geodesic we find that their dispersion relation is by the form

$$E - S = \kappa|\sin\theta|, \tag{10}$$

where κ is a function of the background and θ is the phase of the dressing parameter. Thus the dispersion relation resembles that of the giant magnons found in [45]. We next examine the minimal surfaces obtained by dressing space like geodesics. We show that it is possible to obtain closed strings, they also have a dispersion relation given in (10). These surfaces are pinned at two points on the boundary. These points move on time like trajectories at the boundary.

We finally examine the embedding of the well studied giant gluon solutions of [46, 47] in the BTZ background. These are Euclidean worldsheet solutions. We examine two possible embeddings: In one case these solutions have vanishing energy and spin. The configuration is a spiral which originates from the boundary, contracts and touches the horizon and then expands back to the boundary. In the second solution the embedding solutions has a dispersion relation given by

$$E + S = \kappa \log S. \tag{11}$$

These are spinning spikes which originate from the boundary and touch the horizon.

The organization of the paper is as follows. First we adapt the dressing method developed for the $SU(1,1)$ sigma model to the BTZ background and show that the Virasoro constraints are preserved by the dressing. Then we dress time like geodesics and discuss the properties of the solutions obtained. In section 4 we repeat this analysis for the case of space like geodesics. We then embed the giant gluon solutions in the BTZ background and examine its properties.

Massless scattering at special kinematics as Jacobi polynomials

Last year a new and elegant formula for the complete tree-level S-matrix of pure Yang-Mills and gravity in arbitrary dimensions was proposed in [48] (CHY) and has since enjoyed quite the attention of the scientific community. It was later extended to a massless colored cubic scalar theory [49]. The formula was proven in [50], whereas a string theory derivation was given in [51] and [52]. One of the key aspects of the new formula is its simplicitly. One starts by solving the polynomial in σ_a system of equations (scattering equations)

$$\sum_{b\neq a}^{n} \frac{k_a{\cdot}k_b}{\sigma_a - \sigma_b} = 0, \tag{12}$$

where k_a is the momentum of the a^{th} incoming particle. Then the tree-level scattering amplitude of n-gluons is given by a sum of a Pfaffian with input the solutions of the scattering equations. For gravity the formula is similar with the Pfaffian being replaced by a determinant.

Motivated by the CHY construction, I noticed in [53] that for a special kinematics equation (12) becomes the same equation that the roots of the Jacobi polynomials satisfy. I was then able to further explore this curious coincidence and using properties of the aforementioned polynomials to explicitly construct compact formulae of n-gluon and n-graviton scattering amplitudes. One of the important conclusions of my work is the observation that the roots of the Jacobi polynomials are associated with integrable stuctures, a direction I would like to pursue further.

My results have been recently used for phenomenological studies in [54].

Next to subleading soft-graviton theorem in arbitrary dimensions

Construction and studies of soft theorems, that is the behavior of an amplitude when one of the external particles becomes soft, play an important role in the study of a scattering process. Besides serving as a test for higher point amplitudes, sometimes it can be also used in order to construct the full amplitude of the theory.

Recently, Strominger proposed that a certain infinite-dimensional subgroup of the BMS (Bondi, van der Burg, Metzner, Sachs) supertranslation group is an exact symmetry of the quantum gravity S-Matrix [55]. Weinberg's soft theorem [56, 57] is a Ward identity for this subgroup [58].

It was further conjectured by Cachazo and Strominger [59] that there is a new universal soft graviton theorem which is valid up to next to subleading order in gravity, whose precise formulation can be found in the original reference. One of the natural questions I asked and together with F. Rojas we studied in [60], was whether the aforementioned theorem is valid to an arbitrary number of dimensions. Indeed, the starting point was the CHY formulation (see previous section) and after a long computation we were able to establish the Cachazo-Strominger theorem in arbitrary dimensions (see also [61, 62, 63, 64, 65] for related work). One of the surprises is the fact that the original soft theorem was based on the BMS symmetry, which is only available in four dimensions. Extensions to loop levels is the next possible direction, that I would like to pursue further.

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As vagas de posdoutorado do ICTP-SAIFR foram divulgadas em Physics Today e SPIRES no periodo de 15 november de 2011 ate 31 de janeiro de 2012. As paginas são
http://careers.physicstoday.org/jobs#/detail/458430
http://www.slac.stanford.edu/spires/jobs/ads/96750.shtml

com a seguinte informação:

FAPESP Postdoctoral Positions in Theoretical Physics at the ICTP South American Institute for Fundamental Research

The ICTP South American Institute for Fundamental Research announces the opening of several three-year postdoctoral positions in theoretical physics to begin in 2012. These positions are expected to be filled in the areas of high-energy theory, cosmology, and complex systems, but candidates from all areas of theoretical physics are encouraged to apply.

The ICTP South American Institute for Fundamental Research was recently created in a collaboration of the International Centre for Theoretical Physics (ICTP) and the State University of Sao Paulo (UNESP), and is located at the Instituto de Fisica Terica (IFT-UNESP) campus in Sao Paulo. The institute will have a large number of postdocs and visitors, and five permanent research professors will be hired in the near future.

The FAPESP postdoctoral fellowships are tax-free with an annual salary of 64,000 Brazilian reais (approximately 38,400 US dollars), and pay moving costs as well as 9600 Brazilian reais/year for travel and research expenses. Review of applications will begin in January 2012, so candidates are encouraged to apply before December 31, 2011. The online application form and more information is on the webpage www.ictp-saifr.org

Field of interest: astro-ph, cond-mat, cs, gr-qc, hep-ph, hep-th, math, nucl-th, quant-ph, math-ph
Deadline: Saturday, December 31, 2011
Email: secretary@ictp-saifr.org
More information: http://www.ictp-saifr.org
Letters of Reference should be sent to: www.ictp-saifr.org and secretary@ictp-saifr.org

Recebemos mais que 200 aplicacoes que foram enviadas para o steering committee e conselho cientifico do ICTP-SAIFR e também para professores interessados do IFT-UNESP para receber comentários e avaliações. Os candidatos com as melhores avaliações receberam ofertas do Diretor do ICTP-SAIFR.

Scientific Report

Observational Cosmology and Cosmic Microwave Background

Postdoc: Fabien Lacasa
Supervisor: Nathan Berkovits
FAPESP Process: 2013/19936-6
01/12/2013 to 30/11/2016

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

Scientific report 2014 for ICTP-SAIFR

Fabien Lacasa

I joined the ICTP-SAIFR on the 31st November 2013. Since then, I have begun collaborating in Brazil with Rogerio Rosenfeld (IFT-UNESP), Marocs Lima (USP) and Raul Abramo (USP) and their respective students. I have joined the Dark Energy Survey (DES) collaboration, and in particular the DES-Brazil group. I have maintained my involvement in the Planck collaboartion, and am currently actively participating in the work leading to the imminent 2014 results.

- **Publications**
  Three articles, that I had begun before coming to ICTP, were undergoing the peer-review process. After modifications and exchanges with the respective referees, they entered the publication process and got out this year :

  - *Optimal estimator for the amplitude of the bispectrum from infrared clustered sources*, Lacasa F. and Aghanim N., A.& A. vol. 569, doi: 10.1051/0004-6361/201220751, arXiv:1211.3902
  - *Non-Gaussianity of the cosmic infrared background anisotropies - I. Diagrammatic formalism and application to the angular bispectrum*, Lacasa F. Pénin A. and Aghanim N., MNRAS vol. 439, doi: 10.1093/mnras/stt2373, arXiv:1312.1251
  - *Non-Gaussianity of the cosmic infrared background anisotropies - II. Predictions of the bispectrum and constraints forecast*, Pénin A. Lacasa F. and Aghanim N., MNRAS vol. 439, doi: 10.1093/mnras/stt2372, arXiv:1312.1252

  I also published this year a conference proceeding (see below for the conference details and description of the work) :

  - *"Combining cosmological constraints from cluster counts and galaxy clustering"*, Lacasa F., Proceedings of IAUS 306: Statistical challenges in 21st Century Cosmology (SCCC 21), arXiv:1407.1247

- **Conferences and seminars**
  I participated actively in the scientific activity in São Paulo and Rio de Janeiro, with numerous seminars at UNESP, USP and Observatorio Nacional :

  - Seminars :
    at USP : 'Non-Gaussianity and foregrounds to the CMB' December 2013 (USP workshop), 'Primordial gravitational waves and CMB polarization' March 2014 (invited seminar following BICEP2 results), 'Combining probes of the large scale structure' April 2014 (invited colloquium).
    at ICTP/IFT-UNESP : 'Non-Gaussianity and extragalactic foregrounds to the CMB' February 2014 (ICTP cosmology workshop), 'CMB polarization B modes and primordial gravitational waves' March 2014 (invited seminar following BICEP2 results).
    at Observatorio Nacional Rio : 'Combining probes : cluster counts and galaxy correlation' April 2014.
  - Conference :
    I presented a poster at the international conference : Statistical challenges in 21st Century Cosmology (SCCC 21), International Astronomical Union Symposium (IAUS 306) in Lisboa, May 2014.

  I am also registered for an oncoming conference in January 2015 in Bonamanzi, South Africa.

- **Research and forecasted publications**

I am working with Rogerio Rosenfeld (IFT-UNESP) on how to combine cosmological constraints from cluster counts and galaxy correlation function. This involves modeling their auto and cross-covariances and developing a joint likelihood. I have shown how to model the whole covariance with the halo model complimented with a Halo Occupation Distribution (HOD). I have developed a code computing this large covariance matrix, and obtained results (presented at the Lisboa conference) in the ideal cosmic-variance limited case. I am currently further developing this code to include experimental limitations : photometric redshift errors, mass-observable scatter, purity and completeness of cluster detection... I have also developed an analytical joint likelihood and a method to include Bayesian hyperparameters in this non-Gaussian distribution. This should lead to two articles (covariance modelisation, likelihood and forecasts) in 2015 with Rogerio Rosenfeld.

I am working with Marcos Lima (USP) and his students on a Bayesian method, that I devised, to debias and combine photometric redshift (photo-z) algorithms. The estimation of photo-z in galaxy surveys is indeed one of the limiting aspects to extract cosmological information from current and future galaxy surveys. Bias and failures of photo-z algorithm can degrade cosmological constraints and/or bias them. The first tests of my Bayesian method have shown that it indeed debiases the estimated redshifts distribution, at the price of enlarging error bars. Further tests (see below) will allow to establish whether this can become a competitive method. This should lead to one article with Marcos Lima and DES members in 2015.

I have begun participating in the estimation and analysis of the angular power spectrum for DES with Flavia Sobreira (Fermilab Chicago, DES-Brazil). I am bringing my expertise from CMB analysis so as to produce unbiased and optimal estimations as well as covariance matrices. This will lead to my participation to several DES articles.

I have retained my involvement in the Planck collaboration, in particular in the non-Gaussianity and Sunyaev-Zel'dovich (SZ) working groups. I have contributed by the study of the effect of extragalactic point-sources populations on the estimation of primordial non-Gaussianity. This leads to my participation to the Planck 2014 non-Gaussianity article. I am also currently contributing to the study of the SZ maps through the estimation of the angular bispectrum. This leads to my participation to the Planck 2014 SZ map article. Both articles should come out in late December 2014 or January 2015, with results presented at the December Ferrara conference.

I am working with Aurélie Pénin (University of KwaZulu-Natal, South Africa) on the modelisation of the angular bispectrum of the anisotropies of the Cosmic Infrared Background (CIB). The CIB indeed traces the large scale structure at high redshift and the history of star formation in the universe. Its characterization is thus rich in astrophysical and cosmological information. With a previous model, Aurélie and myself have shown that the bispectrum can contain as much, if not more, astrophysical information as the angular power spectrum. The latter being the current dominant way to study the CIB in the literature. We are now working on an updated and more complex model, that we plan to compare to the Planck measurement that I performed in 2013. This should lead to several articles with Aurélie Pénin, with at least one article in 2015 and possible developments until 2016.

I am finally working with Marcos Lima (USP), Nabila Aghanim Guillaume Hurier and Marian Douspis (IAS Orsay, France) on a model of the SZ angular bispectrum, that I hope to compare to the Planck measurement that I performed in 2013, or the updated measurement that I am currently performing for the Planck 2014 results. Indeed the Sunyaev-Zel'dovich is a probe of the gas physics within galaxy clusters, and it is also highly sensitive to some cosmological parameters (namely σ_8, Ω_m and H_0). The Planck 2013 results have shown tension between the cosmological constraints from SZ and from the CMB. I aim to produce cosmological constraints with the SZ angular bispectrum, and study the different astrophysical and cosmological proposal present in the literature to resolve this cosmological tension with the CMB. I have currently produced a code which predicts the SZ angular power spectrum and bispectrum. It will need to be compared extensively to other (power spectrum only-) codes for validation, before moving on to comparison with data and cosmological constraints. This should lead to one or two articles with Marcos Lima, Nabila Aghanim, Guillaume Hurier and Marian Douspis in 2015 and/or 2016.

Em novembro de 2012, as vagas de pos-doutor foram divulgadas em SPIRES e em FAPESP Oportunidades nas paginas

http://inspirehep.net/record/1197828 e
http://www.fapesp.br/oportunidades/381

Também enviamos cartazes para 500 institutos internacionais com a divulgação das vagas, e colocamos um anuncio em Naturejobs (doi:10.1038/nj0389, published online 12 September 2012).

Recebemos mais que 200 aplicações que foram avaliadas pelo Conselho Cientifico do ICTP-SAIFR e pelos professores interessados do IFT-UNESP. Os candidatos com as melhores avaliações receberam uma oferta do Diretor do ICTP-SAIFR.

Fizemos alguma ofertas que não foram aceitas, e a oferta para Fabien Lacosta foi aceita somente em agosto 2013. Por isso, o processo demorou mais que 6 meses. Não e' possível anexar todos os currículos que recebemos, mas estou anexando currículos de dois candidatos não-escolhidos na seção "Outros documentos".

Cordialmente, Nathan Berkovits

Scientific Report

Gravitational Waves

Postdoc: Saeed Mirshekari
Supervisor: Nathan Berkovits
FAPESP Process: 2013/14754-7
01/09/2013 to 31/08/2015

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

DATA ANALYSIS OF GRAVITATIONAL WAVES

Saeed Mirshekari, ICTP-SAIFR
FAPESP Postdoctoral Research Fellow

November 18, 2014

Abstract

This is a short annual report on my research activities as a postdoctoral research fellow at ICTP-SAIFR since September 2013, requested by FAPESP. In this document, I summerize my research activities during 2014. I also mention a few words about my future research plans.

1 Gravitational Waves Data Analysis

1.1 Introduction

The anticipated completion of upgrades to kilometer-scale, laser interferometric gravitational-wave (GW) observatories in the U.S. (LIGO) and Europe (VIRGO) and their resumption of operations in the 2015 time frame hold the promise to open a new astronomical window in the high-frequency GW band. Since GW signals are extremely weak compared to the background noise, an accurate data analysis is crucial to extract the buried GW signals from the noisy data. Advanced data analysis methods are required in order to provide a mechanism to extract the physical properties of the astronomical GW sources from detected gravitational wave data.

1.2 Waveform Consistencies and Parameter Estimation

In order to compare the efficiency of post-Newtonian waveform approximants that will be used in gravitational waves searches via advanced detectors such as Advanced LIGO and advanced Virgo, we systematically investigate the effect of (A) amplitude corrections, (B) spin precession and (C) waveform bias on the modeling accuracy of gravitational waves emitted by compact binary systems such as black-holes and neutron-stars. We study spinning binaries with and without precession. We quantify our study by computing how effectualness and parameter bias are affected by adding feature A, B and C (individually and as any possible combinations of them) to the injected waveforms. Working with a spin-aligned template bank, we consider both inspiral-only waveform families and inspiral-merger-ringdown waveform approximants. A catalogue of results has been obtained. The numerical calculations has been done mainly through PyCBC toolkit of LIGO Scientific Collaboration (LSC). The research is in its final stages and will be released for publication soon [1]. Preliminary results have been presented to LIGO-Virgo Collaboration at The Numerical and Analytical Relativity and Data Analysis (NARDA) meeting at Fullerton, California and at semi-annual Ligo-Virgo Collaboration meeting at Stanford University in August 2014.

In addition to above project, I recently started to work on a new project focused on parameter estimation of gravitational wave sources in collaboration with colleagues from University of Birmingham. The proposal of this common project has been approved to get tuned by FAPESP and University of Birmingham via contract #2014/50259-3 for 2 years (PI: Riccardo Sturani).

1.3 Contribution to the Waveform Data Analysis Group of LSC [2]

Since ICTP-SAIFR joint LIGO Scientific Collaboration (LSC) in October 2013, the gravity group members of the institute including Riccardo Sturani and myself have been actively collaborating with data analysis group of LIGO. The research activities in this sector are under the Compact Binary Coalescence (CBC) group and the Waveform subgroup of LSC. Presenting my research at NARDA and LVC meetings in this August, I had this great chance to meet many colleagues and interact closely with my collaborators. I visited CGCA group of University of Wisconsin-Milwaukee two times in 2014 in January and September. University of Wisconsin-Milwaukee is a hub for data analysis of LIGO where many colleagues are working from there. During my visit, I had this chance to interact with them and get closely involved in a couple of ongoing projects in data analysis of gravitational waves.

2 Broader Impact

In 2014, I have been actively participating in several seminar talks, schools and workshops of IFT and ICTP-SAIFR. I have been recently informed that my registered talk has been accepted to the next ICTP-Trieste/ICTP-SAIFR Workshop on Observational Cosmology in December.

Our proposal for a summer school on Gravitational Wave in the next year has been approved by the ICTP-SAIFR committee. Among other invited speakers, Clifford Will — a world leader in gravitational wave physics — has approved to participate in this workshop in August 2015 in Brazil.

With Nicolás Bernal, another FAPESP fellow at ICTP-SAIFR, we have continued running the biweekly Journal Club on Astrophysics and Cosmology at IFT-UNESP on Astrophysics and Cosmology (AC/JC). AC/JC has started by the same organizers in November 2013. The participants are faculties, post-docs, and graduate students in the field of high energy physics from IFT-UNESP, ICTP-SAIFR, IAG-USP, and IF-USP. A website has been developed and continuously maintained at https://sites.google.com/site/ictpsaifrjc for a better organization and communication.

Working closely with Sturani, I put an strong effort on learning and developing new skills in Data Analysis and Machine Learning techniques in general, and Data Analysis of Gravitational Waves in particular. I successfully achieved few certificates of some high level online data analysis courses including Machine Learning and R programming offered by Stanford and Johns Hopkins Universities via Coursera. During the past year, I also have gained valuable experiences on working with LAL code which is a massive collection of libraries and routines (in Python and C++ languages) to perform an accurate and comprehensive data analysis to be used as the main data analysis pipeline in advanced detectors such as Advanced LIGO.

I will continue to maintain my website at http://physics.wustl.edu/smirshekari (eventually to be transferred to the ICTP domain) with freely available information related to my research, including links to published papers, links to the notes and presentations, and explanatory information on ongoing research topics. Requested by Riccardo Sturani, I have developed a new website for the ICTP-SAIFR's Gravity Group which soon will be uploaded to http://ictp-saifr.org domain for future benefits for the group.

3 Future Plans

Continuing working on analytical aspects of fundamental general relativity and alternative theories, over the next few years, I intend to also play an active role in Advanced LIGO data analysis group, to effectively contribute to the research programs in astrophysics and data analysis related to the current and future GW detectors, and to expand my research into the areas of astrophysics relevant to GW astronomy.

References

[1] "Accuracy of Post-Newtonian Waveform Approximants in Modeling Compact Binaries with Advanced LIGO and Virgo: A Mutual Consistency Test Catalogue", S. Mirshekari and R. Sturani, in preparation.

[2] "Narrow-Band Search of Continuous Gravitational-Wave Signals from Crab and Vela Pulsars in Virgo VSR4 Data"The LIGO Scientific Collaboration, the Virgo Collaboration: J. Aasi, et al. [Saeed Mirshekari] Preprint: arXiv:1410.8310

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Fizemos alguma ofertas que não foram aceitas, e a oferta para Saeed Mirshekari foi aceita somente em julho 2013. Por isso, o processo demorou mais que 6 meses. Não e' possível anexar todos os currículos que recebemos, mas estou anexando currículos de dois candidatos não-escolhidos na seção "Outros documentos".

Cordialmente, Nathan Berkovits

Scientific Report

Non equilibrium First Principles molecular dynamics of solid/water interfaces: A novel approach to the study of electrochemical processes

Postdoc: Luana Sucupira Pedroza

Supervisor: Nathan Berkovits

FAPESP

Process: 2014/04114-3

01/04/14 to 30/12/14

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

1 Resumo do projeto

From a fundamental potion of view there is little understanding of the interactions at the liquid/solid interfaces. This is mostly due to the disordered nature of the liquid and the difficulty to properly describe it with empirical models. From a an application view, this understanding of the interaction of the water-solid system at an atomic level is extremely important in electrocatalysts for fuel cells, photocatalysis among other systems. To fully accomplish this task it is fundamental to describe all atoms and their interactions using first principles methodology, i.e., without empirical parameters.

However, in a more realistic system applied to catalysis, the metal will be charged. And an accurate calculation of the electrostatic potential at electrically biased metal-electrolyte interfaces is a current challenge for periodic *ab initio* simulations. It is also an essential requisite for predicting the correspondence between the macroscopic voltage and the microscopic interfacial charge distribution in electrochemical fuel cells. This interfacial charge distribution is the result of the chemical bonding between solute and metal atoms, and therefore cannot be accurately calculated with the use of semi-empirical classical force fields. First principles methods, like Density Functional Theory (DFT) becomes then the most appropriate methodology.

We will study in detail the structure and dynamics of aqueous electrolytes at metallic interfaces taking into account the effect of the electrode potential. The electrode potential will be set by using the methodology already developed for the study of electronic transport in nano-structures. The *ab initio* molecular dynamics (AIMD) simulations will be performed with the Siesta program, that is a code for electronic calculations based on DFT.

Furthermore, one of the key issues in the simulation of the aqueous environment is the accurate description of liquid water within density functional theory. Thus, studies on structural and electronic properties of liquid water will be performed, and tested with different approximations within the DFT.

2 Atividades desenvolvidas

Following the need for new - and renewable - sources of energy worldwide, fuel cells using electrocatalysts can be thought of as a viable option. Fuel cells are electrochemical devices; they have a positively charged anode, a negatively charged cathode and an ion-conducting material, the electrolyte. Oxygen passes over one electrode, and hydrogen over the other, generating electricity, water and heat. The optimum and ideal fuel cell device would use both H_2 and O_2 produced *in situ* using solar energy (using a photocatalyst material).

The critical reactions in this process involve the interface between liquid water and a solid crystalline semiconductor or metal. This reactivity is governed by the explicit atomic and electronic structure built at the interface as a response to environmental conditions, such as an applied potential. From a fundamental potion of view there is little understanding of the interactions at the liquid/solid interfaces. This is mostly due to the disordered nature of the liquid and the difficulty to properly describe it with empirical models. To fully accomplish this task it is fundamental to describe all atoms and their interactions using first principles methodology, i.e., without empirical parameters.

However, the accurate calculation of the electrostatic potential at electrically biased interfaces is still a current challenge in calculations using periodic boundary conditions, as done in standard Density Functional Theory (DFT) method [1, 2]. In periodic simulations, charged systems are particularly problematic since their electrostatic energy is divergent. Conventional algorithms automatically impose a charge-neutrality condition, implicitly introducing an artificial jellium background [6]. An spurious interaction between the charged system and the neutralizing background occurs and its correction is not well defined in most of the cases of interest [7].

To correctly compute the effect of an external bias potential applied to electrodes, in this work we use open boundary conditions using the non-equilibrium Green's function (NEGF) method combined with DFT. This is similar to the current methodology used for electronic transport calculations, as implemented in the Smeagol code for example [4]. Indeed we are using this methodology simply to take into account the effects of the bias potential in the electrodes and in the liquid, but not to study the electron transport across the system.

Once Green's function of the scattering region is known, all the observables of the system can be computed. From the final density matrix and with the energy density matrix it is possible to obtain the forces of the system. Within the ground state DFT framework, the computation of forces on the nuclei is trivial thanks to the Hellman-Feynman theorem. The situation is more complex out of equilibrium, where the Hellman-Feynman theorem does not apply [9]. Recently, it was shown that the forces can actually be obtained by the time derivative of the expectation value of the ionic momentum operators [8] and we have implemented this in Smeagol code. We have also implemented the vdW-DF functional [10], which includes van der Waals interactions.

Following our recent work on metal/water interfaces [3] where we have studied the interaction of liquid water with Pd and Au surfaces and motivated by the experimental work of Toney and collaborators [5] we have now applied this methodology to study the electronic properties and forces of one water molecule and water monolayer at the interface of gold electrodes. We find that the water molecule has a different torque direction depending on the sign of the bias applied. We also show that it changes the position of the most stable configuration indicating that the external bias plays an important role in the structural properties of the interface. As a perspective we will apply this methodology to study water monolayer at gold surface and the dynamics of liquid water at different metal surfaces.

3 Atividades academicas

During this year, I went to two national meetings. The first one was the XXXVII Encontro Nacional de Fsica da Matria Condensada, where I gave the talk "First principles molecular dynamics at the electrochemical interface". In this one I was also a co-author of the work "Study of van der Waals corrections combined with different Generalized Gradient-dependent Density Functionals for finite and extended systems". The second one was the XIII Brazilian MRS Meeting (SBPMat), where I gave the talk "First principles analysis of metal/water interaction under the influence of external bias potential". Both meetings had foreign and national researches and were very important to discuss the results of my working.

On December I visited the group of Prof. Gustavo Troiano, at the Instiuto de Quimica (UNESP/Araraquara). There he introduced me to the QM/MM (Quantum Mechanics/Molecular Mechanics) technique, which will be used to the study of the water/metal interfaces.

4 Atividades futuras

In the next few months we will write a manuscript to be submitted to a journal presenting the methodology and the results of the water/Au interface. Also, the results obtained so far will be presented at the APS March Meeting, in San Antonio, USA. Then we will extend the application of the methodology to a monolayer of water in contact to the metal, which can be directly compared to experimental results.

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Em novembro de 2012, as vagas de pos-doutor foram divulgadas em SPIRES e em FAPESP Oportunidades nas paginas

http://inspirehep.net/record/1197828 e
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Na area de sistemas complexos, a melhor candidata foi Luana Pedroza.
Não e' possível anexar todos os currículos que recebemos, mas estou anexando currículos de dois candidatos não-escolhidos na seção "Outros documentos".

Cordialmente, Nathan Berkovits

Scientific Report

Large Hadron Collider Phenomenology

Postdoc: Alberto Tonero
Supervisor: Nathan Berkovits
FAPESP Process: 2013/02404-1
01/04/2013 to 31/03/2016

ICTP-SAIFR / IFT-UNESP
São Paulo, SP
2014

FAPESP SCIENTIFIC REPORT 2014 – ALBERTO TONERO

Research activity

During the year 2014 my research activity at ICTP-SAIFR was focused mainly on two projects related to particle physics phenomenology at the LHC.

The first project I was involved in, together with two collaborators from SISSA (Trieste), consists in studying top quark anomalous couplings in the electro-weak sector using the most recent measurements coming from LHC and Tevatron. Currently available measurements from the Tevatron and the LHC already allow to set stringent limits on possible deviations in the values of these couplings from their Standard Model values. We reviewed and updated limits on possible anomalous couplings in the Wtb interaction vertex. Possible deviations in the interaction between the top quark and the neutral bosons Z and the photon were left out because still poorly measured. We consider data from top quark decay (as encoded in the W-boson helicity fractions) and single-top production (in the t-, s- and Wt-channels). We find improved limits with respect to previous results (in most cases of almost one order of magnitude) and extend the analysis to include four-quark contact interactions operators. We find that new electroweak physics is constrained to live above an energy scale between 430 GeV and 3.2 TeV, depending on the form of its contribution. This work has been accepted for publication in European Physics Journal C. The e-print version is arXiv:1406.5393 [hep-ph].

The second project I worked on, together with Rogerio Rosenfeld (IFT-UNESP) , consists in deriving direct bounds on the coefficients of higher dimensional top quark dipole operators from their contributions to anomalous top couplings that affect some related processes at the LHC. We assumed that the leading contributions to deviations from the Standard Model are encoded in the so-called top quark dipole operators and we present constraints on the coefficients of these operators arising from direct probes at the LHC. Several observables were studied. In our study we include the W-boson helicity fractions in top quark decays, t-channel single top production, top pair production, associated tW production and, for the first time, top pair production in association with a vector boson. In this work we use the available LHC data for the processes listed above and we employ a Markov Chain Monte Carlo method to perform a Bayesian analysis in order to extract the posterior probability distributions for the coefficients of the dipole operators and the 1- and 2- sigma confidence level contours. This work has been published in Physical Review D, 90, 017701. The e-print version is arXiv:1404.2581 [hep-ph].

Research plan

This year I have started, together with R. Rosenfeld (IFT-UNESP), a collaboration with Christoph Englert (Glasgow University) and Michael Spannowsky (Durham University) to work on a systematic investigation of the impact of beyond the Standard Model physics on Z boson pair and Z+Higgs production in the quark and gluon fusion channels using the language of effective field theory. We want to provide numerical codes as well as an in-depth investigation of all effective theory operators that are relevant for these analyses. These deliverables have been identified by the CERN Higgs cross section working group, and our results are guaranteed to have significant impact on ongoing and future analyses in this regard, especially given the close collaboration of the UK theory groups with the local Glasgow

ATLAS group.

My plan is also to complete a work, in collaboration with A. Codello (CP3-Origins, Odense), about some application of the Exact Renormalization Group Equation in order to the study of ultraviolet properties of quantum field theories. We will present a new non-perturbative way to compute correlation functions in quantum field theories that account for the non-trivial renormalization group structure of the theory under consideration. In particular we will show how it is possible to perform a consistent computation of the four-point function in three dimensional scalar theories. The idea is to perform the path integral by weighting the momentum modes that contribute to it accordingly to their RG relevance, i.e. we weight a mode accordingly to the value of the running coupling at that scale. In this way we show that depending on the phase we obtain different resulting four-point functions.

Preprints and publications

- E-print arXiv:1406.5393 [hep-ph], accepted for publication in European Physics Journal C.

- E-print arXiv:1404.2581 [hep-ph], published in the Physical Review D, 90, 017701.

Conferences and workshops

- “Origin of Mass 2014”, 19-22 May 2014, Odense, Denmark

- “Planck 2014”, 26-30 May 2014, Paris, France (talk given)

- “Going On After the LHC8” workshop, 11-15 August 2014, São Paulo, SP, Brazil

- “XXXV Encontro Nacional de Física de Partículas e Campos”, 15-19 September 2014, Caxambu, MG, Brazil (talk given)

- “X SILAFAE”, 24-28 November 2014, Medellin, Colombia (talk given)

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