1. Física Matemática

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Índice

Propagation of foam-liquid fronts in improved oil recovery

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Resumen

A new mathematical model for foam-liquid front propagation in foam improved oil recovery is introduced as an alternative to models developed previously (Grassia, P., Mas-Hernández, E., Shokri, N., Cox, S. J., Mishuris, G., and Rossen, W. R., Analysis of a model for foam improved oil recovery, *Journal of Fluid Mechanics*, vol. 751, pp. 346–405, 2014). The conceptual model establishes that the propagation is in the direction normal to the front. It also requires that at the top boundary of the domain the net driving pressure is maximum and that at the bottom boundary the net driving pressure is zero. These assumptions lead to the so called "pressure-driven growth" model (Shan, D., and Rossen, W. R., Optimal Injection Strategies for Foam IOR, *Society of Petroleum Engineers Journal*, vol. 9, pp. 132–150, 2004). The new model captures the propagation of the front by the reformulation of the "pressure-driven growth" as a Hamilton-Jacobi equation system. The propagation of the front is represented implicitly by the zero-level set curve of a Hamilton-Jacobi solution ϕ, with $\phi < 0$ to the left of the front, and $\phi > 0$ to the right (Osher, S., and Fedkiw, R, Level set methods and dynamic implicit surfaces, *Springer Science & Business Media*, vol. 153, 2006). The numerical contour values are initially formed to coincide with an early-time asymptotic analytical solution of the "pressure-driven growth" model. Through simulation, numerical data are obtained from which graphical representations are generated for the location of the propagation front, and the angle that the front normal makes with respect to the horizontal and the front curvature. By analytical approximation approaches It is possible to confirm the existence of a concavity in the front shape at small times.

Joint work with:
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Integrability in the Skyrme model in (3+1) dimensions from the Einstein-Skyrme system

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Resumen

It will be described how one can discover an integrable sector of the Skyrme model in (3+1)-dimensions using known results in the Einstein-Skyrme system. As an application, it is shown how to compute the number of bound states Skyrmion-AntiSkyrmion in a box as well as the critical Isospin chemical potential

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The non-commutative topology of dirty superconductors: the "case study" of the Spin Hall effect

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Resumen

The BCS theory of superconductors leads to simple lattice models, known as BdG Hamiltonians. The properties of these second-quantize Hamiltonians can be investigate just looking at their first-quantized counterparts which turn out to be matrix-valued lattice models. The physics of these operators is made more interesting by the presence of a discrete symmetries known as particle-hole (PH). According to the parity of the PH-symmetry and to the presence of additional symmetries (spin-rotation, time-reversal, etc.), the (first-quantized) BdG Hamiltonians are classified in classes which are parametrized by topological invariants.

Albeit the physics of these models is well understood in the pure periodic case, a systematic study in the presence of disorder seems to be still missing. One of the main features of the physics of the BdG Hamiltonians is the presence of topological protected states which allow quantized bulk-currents (spin, thermal, etc) and related edge-currents. Such topological quantities have to persist also in the presence of (at least weak) disorder. The aim of this talk is to present first results in this directions.

As explained by Bellissard et co-workers during the 80's - 90's, the natural setting to combine differential topology and randomness is the non-commutative geometry. In this talk I will present the non-commutative (differential) topology associated to dirty BdG Hamiltonians. The PH-symmetry adds to the usual algebraic structure and provides a natural notion of "Reality" (á la Atiyah) which enters in the definitions of the relevant geometric objects. These general results will be tested on the case study of the C-type BdG Hamiltonians in order to provide a non-commutative explanation of the spin quantum Hall effect both in the bulk and on the edge. The content of the talk is based on [1].

Joint work with:
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Relación entre las reglas de Pieri de los polinomios de Jack en el superespacio y el modelo de 6-vértices

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Resumen

Los polinomios de Jack en el superespacio son polinomios simétricos que dependen de un parámetro α. Estos polinomios son funciones propias de la versión supersimétrica del modelo CSM. En esta charla mostraremos las reglas de Pieri para los polinomios de Jack en el superespacio y su relación con el modelo de 6-vértices. [3]

Trabajo realizado en conjunto con:
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Técnica de integración multivariable originada en los diagramas de Feynman

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Resumen

Presentamos un método heurístico destinado a la evaluación de integrales multivariables cuyo intervalo de integración está definido por $[0, \infty[$. Este método se denomina Método de Brackets (MoB, su sigla en inglés) [1,2,3], el cual tiene su origen en los formalismos matemáticos desarrollados en la teoría cuántica de campos para la evaluación de las integrales asociadas a los diagramas de Feynman. En este trabajo presentaremos las reglas que conforman MoB y su aplicación a diversos problemas de integración, tanto de una variable como multivariable.

Es importante mencionar que desde el punto de vista de la evaluación analítica de integrales, el uso de paquetes computacionales, tales como Mathematica o MAPLE, no resultan ser suficientes para los problemas multivariables que aparecen en la matemática aplicada, bajo esta perspectiva es que MoB resulta ser una poderosa herramienta de cálculo para estas integrales. Desde el punto de vista de lo procedural, la tarea fundamental de MoB es convertir la integral en una "serie"muy particular, denominada "serie de brackets", a partir de esta serie y a través de la aplicación de un conjunto de reglas ad-hoc, la solución de la integral se obtiene al resolver un sistema de ecuaciones lineales. A la pregunta: ¿qué es un bracket?, podemos por ahora indicar que es una estructura matemática que representa a una integral divergente, la cual por definición está representada por la siguiente ecuación:

$$\int_0^\infty x^{a_1+...+a_n-1} dx = \langle a_1 + ... + a_n \rangle \tag{1}$$

siendo $\{a_i\}$ $(i = 1, ...n)$ índices arbitrarios y el símbolo $\langle \cdot \rangle$, un bracket. Desde el punto de vista de lo operacional, el comportamiento del bracket es similar al de una delta de Kronecker.

Las ideas relevantes que podemos indicar sobre esta técnica de integración (MoB), es que posee varias ventajas respecto a otras técnicas avanzadas de integración:

- MoB resuelve N integrales múltiples de manera simultánea. Convencionalmente se evaluan N integrales iteradamente.
- MoB no requiere herramientas de cálculo avanzado, solo elementos básicos de álgebra lineal.
- MoB se basa en reglas y procedimientos sistemáticos, un algoritmo. Estas características hacen que esta técnica sea altamente automatizable.

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Analytical solution to DGLAP integro-differential equation

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Resumen

We consider DGLAP integro-differential equation. This equation describes QCD dynamics. We show how it may be solved analytically. We consider the case in which gauge coupling depends on the energy scale. The solution is found by use of the Cauchy integral formula. The solution restricts form of parton distributions as function of transfer momentum and of Bjorken variable.

Joint work with:
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From Desgaperis-Procesi peakons to Hermite-Padé approximants and beyond...

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Resumen

One of the most interesting questions in fluid theory is to describe the emergence of non-smooth waves and the mechanism responsible for the breakdown of regularity. In the last decades several models were proposed of non-smooth waves with integrable structure, the best known of which are Camassa-Holm and Degasperis-Processi equations. These equations possess stable non-smooth solutions, called peakons which, to a large extent, determine the essential properties of solutions, in particular the breakdown of regularity and the onset of shocks (DP).

In this talk we will begin a trip from these peakons solutions of the Degasperis-Processi equations to Hermite-Padé approximants. We will focus in this last stop but, we also will visit other places such as inverse string problems, multiple orthogonal polynomials and Cauchy biorthogonal polynomials, random matrices models and Riemann-Hilbert problems.

Joint work with:
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Jacek Szmigielski[2], Department of Mathematics and Statistics, University of Saskatchewan, Saskatoon, Canada.

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A_∞−álgebras y Teoría de Hodge Generalizada: una aplicación de los Teoremas de Zhou y Merkulov sobre la existencia de estructuras A_∞ en Geometría Riemanniana

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Resumen

El teorema de *Descomposición de Hodge* nos dice que dada una variedad riemanniana, compacta, sin frontera y orientada M, el espacio de las $k-$formas diferenciales se puede descomponer unicamente determinado por:

$$\Omega^k(M) = d\Omega^{k-1}(M) \oplus \delta\Omega^{k-1}(M) \oplus \mathcal{H}^k$$

Esto es, para $\omega \in \Omega^k(M)$, existen $\alpha \in \Omega^{k-1}(M)$, $\beta \in \Omega^{k+1}(M)$ y $\gamma \in \Omega^k(M)$ con $\Delta(\gamma) = 0$, tal que ω se escribe de manera única como $\omega = d\alpha + \delta\beta + \gamma$.

A fines de los 90's, Zhou [Zh] y Merkulov [Me] probaron el siguiente resultado algebraico:
Teorema [Zhou-Merkulov]: *Para toda dga* $(A, d, \circ)$ *con métrica euclidiana o hermitiana tal que* d *tiene un adjunto formal* d^* *y* A *tiene descomposición de Hodge* $A = \mathcal{H} \oplus \mathrm{img}\ d \oplus \mathrm{img}\ d^*$*, existe una estructura de* $A_\infty-$*álgebra en* $\mathcal{H}$ *con multiplicaciones superiores* $m_1 = d$*,* $m_2 = \circ$*, y para* $n \geq 3$ $m_n = (id - [d, G_d d^*])\,\lambda_n$*, con* G_d *el operador de Green y* λ_n *los tensores* λ *de Merkulov.*

Se sigue que el teorema de Hodge implica la existencia de una estructura de álgebra A_∞ asociada naturalmente a una variedad Riemanniana compacta. Nosotros mostramos la existencia de estructuras de $A_\infty-$álgebra sobre variendades Riemannianas compactas diferentes (a priori) a la inducida via el teorema clásico de Hodge.

En la teoría desarrollada por Eiseman y Stone [E-S] en su artículo "A generalized Hodge theory", se tiene que si para una determinada $1-$forma vectorial $\underline{h}$ se desvanece el tensor de Nijenhuis, existe una derivada exterior d_h que tiene un adjunto δ_h con respecto al producto interno usual entre formas diferenciales de una variedad Riemanniana compacta. Este hecho permite definir un operador diferencial Δ_h que es una generalización del operador Laplace-DeRahm. Y en consecuencia se puede obtener una generalización del teorema de la descomposición de Hodge clásica y por lo tanto, usando el teorema de Zhou-Merkulov, una estructura de $A_\infty-$álgebra diferente (a priori) a la canónica.

Trabajo realizado en conjunto con:
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Stability of Sine-Gordon 2-solitons in the energy space

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Resumen

In this talk we will prove that three different 2-soliton solutions of the sine-Gordon equation (SG) are orbitally stable in the natural energy space of the problem [4]. We will prove this result without using the inverse scattering technique for the equation nor the steepest descent method, which allows us to work in the very large energy space $H^1(\mathbb{R}) \times L^2(\mathbb{R})$. The three families which we will study are called 2-kink, kink-antikink and breather of SG, described by Lamb [3]. To prove this result we will use a well-chosen Bäcklund transformation which allow us to reduce the stability question of these families to the zero solution case, in the same spirit as the result of Alejo and Muñoz for the case of the modified Kortweg-de Vries equation [1]. However, we will see that SG presents several new difficulties that we will have to solve appropriately. Possible connections to asymptotic stability results will also be discussed. This work is in colaboration with C. Muñoz and improves in several directions the results in [2].

Joint work with:
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Nonlinear fractional Schrödinger equation with a Hartree type of nonlinearity

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Resumen

We study qualitative properties of the following time fractional nonlinear Schrödinger equation on the Sobolev space $H^{\beta}(\mathbb{R}^n)$

$$\begin{cases} i^{\alpha} D_t^{\alpha} u(t,x) = (-\Delta)^{\beta/2} u(t,x) + \mu J_t^{1-\alpha} K_{\gamma}(|u|^2)(x) u(t,x), & (t,x) \in [0,T] \times \mathbb{R}^n, \\ \qquad u(0,x) = u_0(x), \; u_0 \in H^{\beta}(\mathbb{R}^n), \end{cases} \tag{1}$$

in which $\alpha \in (0,1)$, $\beta \in (0,2)$, $\mu \in \mathbb{R}\backslash\{0\}$. The above equation (1) is investigated under the assumption that D_t^{α} is the fractional Caputo derivative of order α, and $J_t^{1-\alpha}$ is the fractional integral of Riemann-Liouville; see e.g. [1]. Moreover, we consider the nonlocal operator $(-\Delta)^{\beta/2}$ to be defined as a pseudo-differential operator on $\mathbb{R}^n$ (see e.g. [2]). The non-linear term of Hartree type, is given by the convolution operator

$$K_{\gamma}(u)(x) := (|\cdot|^{-\gamma} \psi * u)(x), \qquad u \in H^{\beta}(\mathbb{R}^n),$$

in which ψ is a fixed but arbitrary, positive and bounded function, $0 < \gamma < n$. Then, for suitable choices of the parameters $\alpha, \beta, \gamma, \psi, n$, we prove existence, uniqueness, and regularity properties of solutions for the non-local equation (1).

Joint work with:
H. Prado[1], USACH.

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Simetrías no-locales e integrabilidad

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Resumen

Esta charla es una introducción a la teoría de simetrías no-locales de ecuaciones diferenciales y sus aplicaciones. Esta teoría fue propuesta originalmente por matemáticos rusos hace más de veinte años y ha sido desarrollada en profundidad sólo en el último tiempo. Referencias relevantes son [1, 2, 3, 5, 6] y el texto ya clásico [4].

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Asymptotic dynamics for certain 2-D magnetic quantum systems

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Resumen

In this talk I will present new results concerning the long time localisation in space (dynamical localisation) of certain two-dimensional magnetic quantum systems. The underlying Hamiltonian may have the form $H = H_0 + W$, where H_0 has dense point spectrum and rotational symmetry and W is a perturbation that breaks the symmetry.

Joint work with:
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I. Anapolitanos, D. Hundertmark, S. Wugalter, Institute of Analysis, KIT, Karlsruhe, Germany.

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On the current-current correlation measure for random Schrödinger operators

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Resumen

We review various properties of random Schrödinger operators and recall formulations of conductivity and current-current correlation measure. In this talk we will present a panoramic view and recent results on localized regime. We will focus in particular on the diagonal behaviour problem of the ccc-measure and explain how it is related to the localization length. This is a work in progress with J. Bellissard and G. De Nittis.

Joint work with:
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Quantum time delay for unitary propagators

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Resumen

We give the definition of quantum time delay in terms of sojourn times for unitary propagators in a two-Hilbert spaces setting. We prove that this time delay defined in terms of sojourn times (time-dependent definition) exists and coincides with the expectation value of a unitary analogue of the Eisenbud-Wigner time delay operator (time-independent definition). Our proofs rely on a new summation formula relating localisation operators to time operators and on various tools from functional analysis such as Mackey's imprimititvity theorem, Trotter-Kato Formula and commutator methods for unitary operators. Joint work with Diomba Sambou (PUC).

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SO-flat manifolds

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Resumen

Manifolds endowed with a flat $SO(p,q)$ connection have exceptional features. Minkowski space-time, for example, is Lorentz-flat, which means that inertial frames can be consistently defined in an open region and therefore Special Relativity holds on extended regions. We want to point out that Minkowski space is not unique: in particular, three-dimensional anti-de Sitter space-time is also Lorentz-flat. We discuss other possibilities of SO-flat manifolds, and we suggest a relation with Adams theorem.

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