BOOK OF ABSTRACTS

SS10 - Fourier analysis and PDEs on manifolds and Lie groups

2nd Joint Meeting Brazil-Italy in Mathematics

September 9, 2026

Messina, Italy

Organizers:

Sandro Coriasco, University of Turin
Paulo L. Dattori da Silva, University of Sao Paulo at Sao Carlos (ICMC-USP)
Alexandre Kirilov, Federal University of Paranà

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SS10

Degenerate 3-evolution equations in Gevrey classes

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We consider the initial value problem for a $3-$*evolution operator* P with variable coefficients and real characteristics, namely

$$P = D_t + a_3(t)D_x^3 + a_2(t,x)D_x^2 + a_1(t,x)D_x + a_0(t,x), \tag{1}$$

where $a_3 \in C([0,T],\mathbb{R})$ $a_j \in C([0,T];\mathcal{B}^\infty(\mathbb{R})), j = 0,1,2$, and $\mathcal{B}^\infty(\mathbb{R})$ is the space of complex-valued functions bounded on $\mathbb{R}$ together with all their derivatives.

We assume that $a_3(t)$ vanishes with finite order at $t = 0$:

$$\exists \ell > 0 : \ c_{a_3} t^\ell \leq |a_3(t)| \leq C_{a_3} t^\ell, \quad \forall t \in [0,T]$$

for some $0 < c_{a_3} \leq C_{a_3}$. In this situation, the equation degenerates and the (t,x)-behavior of the lower order terms becomes crucial to obtain well-posedness results. We assume the following Levi-type conditions: there exists positive constants k, k', σ_1, σ_2, such that for every $\beta \in \mathbb{N}$, $(t,x) \in [0,T] \times \mathbb{R}$

$$|\partial_x^\beta a_2(t,x)| \leq t^k C_{a_2}^{\beta+1} \beta! \langle x \rangle^{-\sigma_2}, \quad |\partial_x^\beta a_1(t,x)| \leq t^{k'} C_{a_1}^{\beta+1} \beta! \langle x \rangle^{-\sigma_1}, \quad |\partial_x^\beta a_0(t,x)| \leq C_{a_0}^{\beta+1} \beta!.$$

We show that:

- if a_2 degenerates in time with degeneracy gap $\ell - k > 0$, then the Cauchy probem is well-posed in suitable Gevrey-Sobolev spaces, and the (t,x)-behaviors of the coefficients (i.e., the parameters $k, k', \sigma_2, \sigma_1$) play together to determine well-posedness spaces;
- if only a_1 degenerates in time with degeneracy gap $\ell - k' > 0$, then Sobolev well-posedness can be recaptured if its decay as $x \to \infty$ is not-too-slow and $\ell - k'$ is small enough; otherwise, Gevrey-Sobolev well-posedness holds in spaces depending on $\sigma_2, \sigma_1, \ell, k'$;
- if there is no degeneracy in time ($k, k' \geq \ell$), only the x-decay rates σ_2, σ_1 determine the well posedness spaces, and Sobolev well-posedness can be recaptured if the two decays are not-too-slow.

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SS10

Time-Periodic Evolution Equations

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We discuss global properties of certain classes of evolution equations that are periodic in the time variable. The key tool in our approach is a characterization of the functional spaces in terms of Fourier analysis via eigenfunction expansions generated by a fixed elliptic differential operator. Hence, by employing a corresponding discretization process, we provide both necessary and sufficient conditions for the global solvability and global hypoellipticity of the equations under investigation.

The results are based on joint works with Alexandre Kirilov (UFPR-Brazil), Marco Cappiello (Unito-Italy), Matteo Bonino (Unito-Italy), and Sandro Coriasco (Unito-Italy).

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SS10

Global solvability in time-periodic Gelfand-Shilov spaces for a class of first order operators

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We investigate the global solvability in time-periodic Gelfand–Shilov spaces, cf. [1], for the first-order operator $L = \partial_t + a(x)\partial_x$ on $\mathbb{T} \times \mathbb{R}$, where $a(x)$ is a smooth real-valued function satisfying global Gevrey estimates on $\mathbb{R}$ and a suitable *slow decay* condition at infinity. We establish a complete characterization of global solvability in terms of the structure of the zero set of $a(x)$ in the non-compact setting $\mathbb{T} \times \mathbb{R}$. The same operator had been studied in [2] for $(t, x) \in \mathbb{T}^2$ and $a \in C^\infty(\mathbb{T}; \mathbb{R})$ in the C^∞ framework.

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SS10

Involutive systems on non-compact manifolds

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We study the operator

$$L = dt + \sum_{k=1}^{m} \omega_k \wedge \partial_{x_k}, \tag{1}$$

acting on differential forms over a product manifold of the form $M \times \mathbb{T}^m$, where M a smooth manifold and $\omega_1, ..., \omega_m$ are smooth closed 1-forms on M. The characterisations of the hypoellipticity and solvability properties of operators of the form (1) are well-known when M is a closed manifold (that is, compact and without boundary; see, e.g., [1,2]). On the other hand, the cases where M is a non-compact manifold are not equally investigated. We show that when M is non-compact with a certain "structure at infinity", it is still possible to characterise the global hypoellipticity and global solvability of L in terms of arithmetic properties of the forms $\omega_1, ..., \omega_m$.

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L^1 estimates for a dissipative system of elastic waves

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In this talk, we discuss some recent results concerning $L^p - L^q$ estimates for a dissipative system of elastic waves ($\mu > \lambda > 0$ and $\varepsilon > 0$):

$$\begin{cases} \big(\partial_{tt} - \lambda\Delta - (\mu-\lambda)\nabla \operatorname{div} + 2\varepsilon\partial_t\big)U = 0, & (t,x) \in (0,\infty)\times\mathbb{R}^n, \\ (U,U_t)(0,x) = (0,U_1)(x), & x \in \mathbb{R}^n, \end{cases} \tag{1}$$

with a special emphasis on L^1 estimates. A crucial role is played by the real Hardy space $H^1(\mathbb{R}^n)$, equipped with norm

$$\|f\|_{H^1} = \|f\|_{L^1} + \sum_{j=1}^{n} \|R_j f\|_{L^1},$$

where R_j are the Riesz transforms. In particular, the following case is of interest.

Theorem 1. *In space dimension $n = 2$, the following estimates hold:*

$$\|U(t,\cdot)\|_{L^1} \le C\,t\,(1+\varepsilon t)^{-1}\,\|U_1\|_{L^1},$$
$$\|U(t,\cdot)\|_{L^2} \le C\,\lambda^{-\frac{1}{2}}\,\big(\varepsilon t\,(1+\varepsilon t)^{-\frac{3}{2}}\,\|U_1\|_{L^1} + e^{-\varepsilon t}\,\|U_1\|_{H^1}\big),$$

where $C > 0$ independent on U_1. In space dimension $n = 3$, the following estimate holds:

$$\|U(t,\cdot)\|_{L^1} \le C\,t\,\big((1+\varepsilon t)^{-1}\,\|U_1\|_{L^1} + e^{-\varepsilon t}\,(1+\varepsilon t)^{\frac{3}{2}}\,\|U_1\|_{H^1}\big).$$

[1] The results have been partially obtained during the stay of the second author at the Department of Mathematics of University of Bari in the period September 2025-February 2026.
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SS10

Global properties of tube-type systems of vector fields on compact manifolds

Paulo L. Dattori da Silva [1]
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In this talk we will describe global properties of involutive structures defined on a smooth product manifold $M \times \mathbb{T}^m$, where $\mathbb{T}^m \simeq \mathbb{R}^n/2\pi\mathbb{Z}^m$ is the m-dimensional torus.

Given a compact n-dimensional manifold M and closed 1-forms $\omega_1, \dots, \omega_m$ over M, consider the product manifold $\Omega = M \times \mathbb{T}^m$ and the subbundle $\mathcal{V} \subset \mathbb{C}T\Omega$ annihilated by all the forms

$$\zeta_k = \mathsf{d}x_k - \omega_k, \quad k \in \{1, \dots, m\},$$

where $(x_1, \dots, x_m)$ are angular coordinates on $\mathbb{T}^m$. Such a bundle is involutive, and gives rise to a complex of vector bundles over Ω and first-order differential operators between them.

Let Λ^1 be the bundle of complex 1-forms over M, and $\Lambda^{0,1}$ be its pullback to Ω via the natural projection $\Omega \to M$; we denote their spaces of smooth sections by $\Lambda^1 C^\infty(M)$ and $\Lambda^{0,1}C^\infty(\Omega)$, respectively. We define $\mathbb{L} : C^\infty(\Omega) \to \Lambda^{0,1}C^\infty(\Omega)$ by the formula

$$\mathbb{L}f = \mathsf{d}_t f + \sum_{k=1}^{m} \omega_k \wedge \partial_{x_k} f,$$

where $t \in M$ and d_t is the exterior derivative on M; hence, $\mathbb{L}$ is a first-order differential operator.

We will investigate the existence and regularity of global solutions of the equation $\mathbb{L}u = f$.

Also, we will consider related problems on the product $M \times G$, where G is a compact Lie group.

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SS10

Smoothing properties of third order operators with variable coefficients

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In this talk, we will discuss the smoothing properties of some third-order equations with variable coefficients modeling KdV-type equations in arbitrary space dimensions. We will describe the role of the nontrapping condition in the smoothing effect and relate it to our setting. Finally, well-posedness results for nonlinear initial value problems associated with this class of operators will be presented.

This talk is based on a joint work with D. Tramontana.

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Global Properties and Normal Forms in Mixed Fourier Spaces

Alexandre Kirilov
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In this talk, I will discuss a spectral approach to global properties of invariant operators on product spaces $\mathbb{T}^m \times \mathbb{M}$, where $\mathbb{T}^m$ denotes the m-dimensional torus, and $\mathbb{M}$ is a smooth manifold endowed with a linear operator P admitting a discrete spectral decomposition. Natural examples of this abstract setting include time-periodic Gelfand–Shilov spaces on $\mathbb{T}^m \times \mathbb{R}^n$ and operators on $\mathbb{T} \times M$, where M is a compact manifold.

The construction is based on a mixed Fourier analysis combining Fourier series in the periodic variable with the eigenfunction expansion associated with P. We present the definition of the resulting mixed Fourier spaces and describe how invariant operators are represented through their mixed symbols. In this diagonal setting, global hypoellipticity and global solvability can be characterized by precise exponential lower bounds on the mixed symbol away from the resonant set, providing a common spectral viewpoint for several time-periodic models.

This work is being developed in collaboration with M. Ruzhansky from UGent, and was inspired by a series of previous works involving F. de Ávila, W. de Moraes, and P. Tokoro from the Federal University of Paraná, Brazil, and M. Cappiello from the University of Turin, Italy.

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Semilinear Damped Wave Equations with Potential on Compact Lie Groups

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In a recent project we study semilinear damped wave equations on compact Lie groups. More precisely, we consider a time-dependent potential in front of the power nonlinearity. The interaction between this potential and both the linear and nonlinear parts of the equation is exploited. In particular we discuss global existence result and lifespan estimates for blowing-up solution in the complementary case.

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Global hypoellipticity of involutive systems on non-compact manifolds

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We study the global hypoellipticity of the operator

$$\mathbb{L} = \mathrm{d}_t + \sum_{k=1}^{m} \omega_k \wedge \partial_{x_k},$$

defined on differential forms over a product manifold of the form $M \times \mathbb{T}^m$, where M is a non-compact manifold satisfying certain geometric and topological conditions, and $\omega_1, \ldots, \omega_m$ are smooth closed 1-forms on M. Such operators are naturally associated with involutive subbundles of the complexified tangent bundle of $M \times \mathbb{T}^m$. Extending previous results obtained in the compact setting (see [1,2]), we characterize the global hypoellipticity and global solvability of $\mathbb{L}$ in terms of arithmetic properties of the forms $\omega_1, \ldots, \omega_m$.

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[1] This study was financed in part by CAPES – Brasil (Finance Code 001) and CNPq – Brasil (grant 420814/2025-6).

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SS10

Global Properties of Operators on Compact Lie Groups and Beyond

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In this talk, we will discuss the global solvability and global hypoellipticity of left-invariant operators on compact Lie groups. Due to the fact that these operators act as Fourier multipliers, we can use the Fourier analysis based on irreducible unitary representations to study their properties through their symbols. We will start with a short historical background, move on to our recent contributions involving evolution equations and Vekua-type operators in different functional spaces, and point out possible future directions in closed manifolds in general and also for non-compact manifolds. Throughout the talk, we will illustrate these concepts with examples on the torus and SU(2).

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[1]The author was supported in part by CNPq-Brasil (Grant Nos. 420814/2025-6 and 301573/2025-5) and by Sociedade Brasileira de Matemática (SBM).
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