Sesión Especial 14

Harmonic Analysis

Organizadores

- José Manuel Conde Alonso (Universidad Autónoma de Madrid)
- Teresa Luque (Universidad Complutense de Madrid)
- Carlos Pérez (Basque Center for Applied Mathematics - BCAM)

Descripción

El análisis armónico es una disciplina con gran tradición en la Matemática española. En esta sesión habrá charlas de temas herederos de esa tradición y otros aledaños, incluyendo teoría cuantitativa de pesos, teoría geométrica de la medida, espacios L^p no conmutativos, análisis en espacios no homogéneos y aplicaciones a las ecuaciones en derivadas parciales.

Programa

Martes, 5 de febrero (tarde)

17:00 – 17:30	Ioannis Parissis (Universidad del País Vasco & Ikerbasque) *Maximal directional averages along algebraic varieties*
17:30 – 18:00	Virginia Naibo (Kansas State University) *Endpoint estimates for bilinear pseudodifferential operators with homogeneous symbols*
18:00 – 18:30	David Beltran (Basque Center for Applied Mathematics - BCAM) *The k-plane transform and Fourier extension operators*
18:30 – 19:00	Mateus Sousa (LMU Munich) *Recent progress in sharp Fourier restriction theory*

Jueves, 7 de febrero (mañana)

11:30 – 12:00	Rodolfo Torres (University of Kansas) *John-Nirenberg inequalities and weight invariant BMO spaces*
12:00 – 12:30	Luz Roncal (Basque Center for Applied Mathematics - BCAM) *Some observations on the infinite-dimensional torus*

12:30 – 13:00 Adrián González (KU Leuven)
Pseudodifferential calculus and deformed Euclidean spaces

13:00 – 13:30 Runlian Xia (Instituto de Ciencias Matemaíticas (ICMAT))
Algebraic Calderoń-Zygmund theory

Jueves, 7 de febrero (tarde)

15:30 – 16:00 Guillermo Rey (University of Minnesota)
Sparse domination and the strong maximal function

16:00 – 16:30 Kangwei Li (Basque Center for Applied Mathematics - BCAM)
Bloom type inequalities in the bi-parameter setting

16:30 – 17:00 Frédéric Bernicot (CNRS - Université de Nantes)
Frequency localization in the sparse domination

17:30 – 18:00 María Carmen Reguera (University of Birmingham)
Sparse forms for Bochner-Riesz operators

Viernes, 8 de febrero (mañana)

09:00 – 09:30 Olli Saari (University of Bonn)
Variations on Gehring's lemma

09:30 – 10:00 Cristina Benea (Université de Nantes)
On a bilinear maximal square function

10:00 – 10:30 Diego Maldonado (Kansas State University)
On certain degenerate (or singular) divergence-form elliptic PDEs

10:30 – 11:00 Oliver Dragičević (University of Ljubljana)
Generalized convexity of power functions and applications

11:30 – 12:00 Mihalis Mourgoglou (Universidad del País Vasco & Ikerbasque)
Recent developments on free boundary problems for harmonic measure

12:00 – 12:30 Laura Prat (Universitat Autònoma de Barcelona)
L^2-boundedness of gradients of single layer potentials and uniform rectifiability

12:30 – 13:00 Joan Mateu (Universitat Autònoma de Barcelona)
Singular integral operators and rectifiabilty

The k-plane transform and Fourier extension operators

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Abstract. The goal of this talk is to describe some connections between the k-plane transform and Fourier extension operators. In particular, we will show estimates in $L^2(\mathbb{R}^n)$ for the $(n-2)$-plane transform of $|\widehat{fd\sigma}|^2$ whenever $d\sigma$ is the induced Lebesgue measure on the sphere S^{n-1} or the Lorentz-invariant measure on the hyperboloid H^{n-1}. Our estimates are bilinear in nature and will in fact follow from certain similar-flavoured *identities*. Such identities may be interpreted as higher-dimensional analogues of the classical $L^2(\mathbb{R}^2)$ bilinear estimate for Fourier extension operators associated to curves in $\mathbb{R}^2$.

Joint work with Luis Vega.

On a bilinear maximal square function

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Abstract. A natural generalisation of Rubio de Francia's square function to the bilinear setting is associated to a collection of arbitrary strips $\xi - \eta \in [a_k, b_k]$, where $[a_k, b_k]_k$ is an arbitrary collection of disjoint intervals. That is, we are interested in the boundedness of the bilinear operator

$$(f,g) \mapsto (\sum_{k=1}^{N} |\int_{\mathbb{R}^2} \hat{f}(\xi)\hat{g}(\eta) 1_{[a_k,b_k]}(\xi-\eta) d\xi d\eta|^2)^{1/2}.$$

The only case fully understood is that of uniformly distributed intervals of equal lengths (due to Bernicot). We introduce a certain maximal square function that could shed some light on the general case. The operator norm that we obtain is $\sim (\log N)^{10}$.

Joint work with Marco Vitturi.

Frequency localization in the sparse domination

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Abstract. Dominating an operator (or its bilinear dual form) through a sparse sum of local averages have been extensively studied these last years, since it gives a very efficient way to obtain sharp weighted estimates. We aim to understand, how we can keep and track some informations of the initial operator, inside this sparse domination. One of the main results that we will describe is the following: for T a haar multiplier and two L^2-functions f, g then there exists a sparse collection $\mathcal{S}$ of intervals such that

$$|\langle Tf, g\rangle| \lesssim \sum_{I\in\mathcal{S}} < |S_I f|^p >_I^{1/p} < |S_I f|^q >_I^{1/q} |I|,$$

where $< >_I$ denotes the average on I, $p, q > 0$ are arbitrary exponent and S_I is the localized square function on I. By keeping the frequency representation of the Haar multiplier, we can obtain localized square function inside the averages of the sparse domination and that allows us to get L^p (or L^q) average for arbitrary exponents $p, q > 0$. We will then describe some applications for the boundedness of such operators in weighted Hardy spaces.

Referencias

[1] C. Benea and F. Bernicot, Conservation de certaines propriétés à travers un contrôle épars d'un opérateur et applications au projecteur de Leray-Hopf. Annales de l'Institut Fourier (2018).

Joint work with Cristina Benea
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Generalized convexity of power functions and applications

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Abstract. Let $p > 1$. We define and study generalized convexity of power functions $|\zeta|^p$ with complex ζ in presence of complex accretive matrices. We present a few results in harmonic analysis and PDE whose validity depends on the convexity in question. Our main tool is a variant of a heat flow associated with a particular *Bellman function*.

Referencias

[1] A. Carbonaro, O. Dragičević: Convexity of power functions and bilinear embedding for divergence-form operators with complex coefficients, https://arxiv.org/abs/1611.00653

Joint work with Andrea Carbonaro (University of Genova).
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Pseudodifferential calculus and deformed Euclidean spaces

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Abstract. In its pioneering work, Alain Connes introduced the notion of pseudodifferential calculus over noncommutative spaces. Those objects include as a model case the so-called quantum tori, which are deformed versions of the usual n-dimensional torus $\mathbf{T}^n$. In this talk we will present recent results over pseudodifferential operators in quantum Euclidean spaces, which can be understood as deformed versions of $\mathbf{R}^n$ whose relation with quantum tori is similar to that of Euclidean spaces with flat tori. In particular, we will give boundedness results for pseudodifferential operators over noncommutative L_p-spaces. Those results are obtained by means of a generalized noncommutative Calderón-Zygmund theory, the first instance of such theory that do not require semicommutative assumptions. As a corollary, we obtain boundedness theorems for pseudodifferential operators on quantum tori via a periodization argument.

Joint work with Marius Junge and Javier Parcet
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Bloom type inequalities in the bi-parameter setting

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Abstract. I will present some recent work on the Bloom type inequalities in the bi-parameter case. To be precise, we are concerned with the $L^p(\mu) \to L^p(\lambda)$ boundedness of $[b, T]$ and its higher order case, where T is a bi-parameter Calderón-Zygmund operator, $\mu, \lambda \in A_p$ and $b \in \mathrm{bmo}(\nu)$ with $\nu = \mu^{\frac{1}{p}} \lambda^{-\frac{1}{p}}$. Lower bounds are also provided. The first order case is given by Holmes-Petermichl-Wick [2], we provided a simpler proof and our idea allows us to complete the higher order case (see [4]). Moreover, we also study the $L^p(\mu) \to L^p(\lambda)$ boundedness of $[T_1, [b, T_2]]$, where $b \in \mathrm{BMO}_{\mathrm{prod}}(\nu)$ and T_1, T_2 are one-parameter Calderón-Zygmund operators on $\mathbb{R}^n$ and $\mathbb{R}^m$, respectively (see [5]). For this case, the lower bound is still open (in the unweighted case, see Ferguson-Lacey [1] for the Hilbert transform and Lacey-Petermichl-Pipher-Wick [3] for the Riesz transform).

Referencias

[1] S. Ferguson, M. Lacey, A characterization of product BMO by commutators, Acta Math. 189 (2002) 143–160.

[2] I. Holmes, S. Petermichl, B. Wick, Weighted little bmo and two-weight inequalities for Journé commutators, Anal. PDE 11 (2018) 1693–1740.

[3] M. Lacey, S. Petermichl, J. Pipher, B. Wick, Multiparameter Riesz commutators, Amer. J. Math. 131 (2009) 731?769.

[4] K. Li, H. Martikainen, E. Vuorinen, Bloom type inequality for bi-parameter singular integrals: efficient proof and iterated commutators, preprint, arXiv:1806.02742, 2018.

[5] K. Li, H. Martikainen, E. Vuorinen, Bloom type upper bounds in the product BMO setting, preprint, arXiv:1810.09303, 2018.

Joint work with Henri Martikainen and Emil Vuorinen

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On certain degenerate (or singular) divergence-form elliptic PDEs

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Abstract. This talk, based on the work [2], will be about regularity properties for solutions to $\mathcal{L}^{\varphi}_{A,b,c}(u) = f\mu_\varphi$ in $\Omega \subset \mathbb{R}^n$ (open and convex), where $\mathcal{L}^{\varphi}_{A,b,c}$ denotes the divergence-form elliptic operator

$$\mathcal{L}^{\varphi}_{A,b,c}(u) := \operatorname{div}(A\nabla u) + \langle b, \nabla u\rangle \mu_\varphi + cu\mu_\varphi$$

where, for some $0 < \lambda \leq \Lambda$, the $n \times n$ matrix $A = A(x)$, a.e. $x \in \Omega$, satisfies

$$\lambda\, \mathcal{A}_\varphi \leq A \leq \Lambda\, \mathcal{A}_\varphi \qquad \text{a.e. in } \Omega$$

in the sense of positive-definite matrices, with

$$\mathcal{A}_\varphi(x) := \det D^2\varphi(x)\, D^2\varphi(x)^{-1} \quad \text{a.e. } x \in \Omega.$$

Here $\varphi : \Omega \to \mathbb{R}$ belongs to a suitable class of strictly convex functions and $\mu_\varphi := \det D^2\varphi$ denotes its Monge-Ampère measure.
This work represents an extension of the De Giorgi-Nash-Moser regularity theory, which corrresponds to the particular choice $\varphi(x) = |x|^2/2$.
The case of nondivergence-form elliptic operators has been addressed in [1].

Referencias

[1] D. Maldonado, *On certain degenerate and singular elliptic PDEs I: nondivergence form operators with unbounded drifts and applications to subelliptic operators*, J. Differential Equations, 264 (2), (2018), 624–678.

[2] D. Maldonado, *On certain degenerate and singular elliptic PDEs II: divergence-form operators, Harnack inequalities, and applications*, J. Differential Equations, to appear.

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Singular integral operators and rectifiabilty

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Abstract. In this talk we will discuss on the connections between the analytic properties of singular integral operators defined in $L^2(\mu)$ and the geometric properties of the measure μ.
More precisely, we will give a family of singular integral operators in the plane T_t such that the $L^2(H^1\lfloor E)$-boundedness of these operators implies that E is a rectifiable set. It is well known that this property is satisfied for the Cauchy transform.

Joint work with Petr Chunaev and Xavier Tolsa

Recent developments on free boundary problems for harmonic measure

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Abstract. In this talk we will give an overview of the recent developments on free boundary problems for harmonic measure. In particular, we will discuss the connection between uniform rectifiability of the boundary of the domain with scale invariant PDE estimates for bounded harmonic functions as well as certain quantitative absolute continuity assumptions for harmonic measure with respect to the Hausdorff measure on the boundary.

Referencias

[1] J. Azzam, J. Garnett, M. Mourgoglou, and X. Tolsa. *Uniform rectifiability, elliptic measure, square functions, and ε-approximability via an ACF monotonicity formula.* Preprint (2017) arXiv:1612.02650.

[2] J. Azzam, M. Mourgoglou, and X. Tolsa. *Harmonic measure and quantitative connectivity: geometric characterization of the L^p solvability of the Dirichlet problem. Part II.* Preprint (2018) arXiv:1803.07975.

[3] J. Garnett, M. Mourgoglou, and X. Tolsa. *Uniform rectifiability in terms of Carleson measure estimates and ε-approximability of bounded harmonic functions.* Duke Math. J. Vol. 167 (2018), No. 8, 1473-1524.

[4] S. Hofmann, P. Le, J. M. Martell and K. Nyström. *The weak-A_∞ property of harmonic and p-harmonic measures implies uniform rectifiability.* Anal. PDE 10 (2017), no. 3, 653–694.

[5] S. Hofmann and J.M. Martell. *Harmonic measure and quantitative connectivity: geometric characterization of the L^p solvability of the Dirichlet problem. Part I.* Preprint arXiv:1712.03696 (2017).

[6] M. Mourgoglou and X. Tolsa. *Harmonic measure and Riesz transform in uniform and general domains.* To appear in J. Reine Angew. Math., DOI: 10.1515/crelle-2017-0037 (2017).

Endpoint estimates for bilinear pseudodifferential operators with homogeneous symbols

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Abstract. The estimates

$$\|D^s(fg)\|_{L^p} \lesssim \|D^s f\|_{L^p}\|g\|_{L^\infty} + \|f\|_{L^\infty}\|D^s g\|_{L^p}, \tag{1}$$

where D^s is the fractional differentiation operator of order $s > 0$ and $1 < p < \infty$, and related commutator estimates, play an important role in the treatment by Kato–Ponce [1] of the Cauchy problem for the Euler and Navier–Stokes equations in the setting of Sobolev spaces. The endpoint case $p = \infty$ of (1) was first addressed by Grafakos–Maldonado–Naibo [4] and then settled by Bourgain–Li [3].
In this talk, we will present a unifying approach to establish mapping properties of the type

$$\|D^s(T_\sigma(f,g))\|_Z \lesssim \|D^s f\|_X\|g\|_{L^\infty} + \|f\|_{L^\infty}\|D^s g\|_X,$$

where T_σ is a bilinear pseudodifferential operator associated to a homogeneous symbol and the function spaces Z and X admit molecular characterizations in the sense of Frazier–Jawerth [2]. Particular cases of these results include (1) and the following endpoint estimates:

$$\|D^s(T_\sigma(f,g))\|_{BMO} \lesssim \|D^s f\|_{BMO}\|g\|_{L^\infty} + \|f\|_{L^\infty}\|D^s g\|_{BMO}.$$

Referencias

[1] T. Kato and G. Ponce. Commutator estimates and the Euler and Navier-Stokes equations. *Comm. Pure Appl. Math.*, 41(7):891–907, 1988.

[2] M. Frazier and B. Jawerth. A discrete transform and decompositions of distribution spaces. *J. Funct. Anal.*, 93(1):34–170, 1990.

[3] J. Bourgain and D. Li. On an endpoint Kato-Ponce inequality. *Differential Integral Equations*, 27(11-12):1037–1072, 2014.

[4] L. Grafakos, D. Maldonado, and V. Naibo. A remark on an endpoint Kato-Ponce inequality. *Differential Integral Equations*, 27(5-6):415–424, 2014.

Joint work with Joshua Brummer.
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Maximal directional averages along algebraic varieties

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Abstract. I will give a brief overview of the area of directional singular integrals and maximal averages on $\mathbb{R}^n$. More precisely I will give an account of the problem of bounding singular and maximal averages along sets of directions. My main interest is in the case of finite, but otherwise *arbitrary* sets of directions in higher dimensions ($n \geq 3$). I will present some recent results on the L^2-boundedness of such averages in the case that the directions lie on a k-dimensional algebraic variety in $\mathbb{R}^n$; these bounds are sharp, up to ε-losses, in terms of the cardinality of the set of directions; the proof uses an inductive scheme based on the polynomial partition of finite sets lying on algebraic varieties. Previous results for *equidistributed* directions on *curves* can be found in the work of Córdoba, [2], and Barrionuevo, [1]. This talk reports on joint work [3] with Francesco Di Plinio (University of Virginia).

Referencias

[1] Jose Barrionuevo, *Averages along uniformly distributed directions on a curve*, Proc. Amer. Math. Soc. **119** (1993), no. 3, 823–827.

[2] Antonio Córdoba, *Geometric Fourier analysis*, Ann. Inst. Fourier (Grenoble) **32** (1982), no. 3, vii, 215–226.

[3] Francesco Di Plinio and Ioannis Parissis, *Maximal directional operators along algebraic varieties*, (2018), arXiv:1807.08255.

Joint work with Francesco Di Plinio (University of Virginia)
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L^2-boundedness of gradients of single layer potentials and uniform rectifiability

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Abstract. Let $A(\cdot)$ be an $(n+1)\times(n+1)$ uniformly elliptic matrix with Hölder continuous real coefficients and let $\mathcal{E}_A(x,y)$ be the fundamental solution of the PDE $\operatorname{div}(A(\cdot)\nabla u(\cdot))(x)=0$ in $\mathbb{R}^{n+1}$. Let μ be a compactly supported n-AD-regular measure in $\mathbb{R}^{n+1}$ and consider the singular integral operator

$$T_\mu f(x)=\int \nabla_x \mathcal{E}_A(x,y)\, f(y)\, d\mu(y).$$

We show that if T_μ is bounded in $L^2(\mu)$, then μ is uniformly n-rectifiable. This extends the solution of the codimension 1 David-Semmes problem for the Riesz transform to the gradient of the single layer potential. Together with a previous result of Conde-Alonso, Mourgoglou and Tolsa, this shows that, given $E\subset\mathbb{R}^{n+1}$ with finite Hausdorff measure $\mathcal{H}^n$, if $T_{\mathcal{H}^n|_E}$ is bounded in $L^2(\mathcal{H}^n|_E)$, then E is n-rectifiable.

Joint work with Carmelo Puliatti and Xavier Tolsa

Sparse forms for Bochner-Riesz operators

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Abstract. Sparse operators are positive dyadic operators that have very nice boundedness properties. The L^p bounds and weighted L^p bounds with sharp constant are easy to obtain for these operators. In the recent years, it has been proven that singular integrals (cancellative operators) can be pointwise controlled by sparse operators. This has made the sharp weighted theory of singular integrals quite straightforward. The current efforts focus in understanding the use of sparse operators to bound rougher operators, such as oscillatory integrals. Following this direction, our goal in this talk is to describe the control of Bochner-Riesz operators by sparse operators.

Joint work with M. Lacey and D. Mena

Sparse domination and the strong maximal function

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Abstract. We study the problem of dominating the dyadic strong maximal function by $(1,1)$-type sparse forms based on rectangles with sides parallel to the axes, and show that such domination is impossible. Our proof relies on an explicit construction of a pair of maximally separated point sets with respect to an appropriately defined notion of distance.

Joint work with Alexander Barron, José Conde-Alonso, and Yumeng Ou.

Some observations on the infinite-dimensional torus

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Abstract. We will show a Calderón–Zygmund decomposition associated to a function $f \in L^1(\mathbb{T}^w)$, where $\mathbb{T}^w$ is the infinite torus. The idea relies on an adaptation of a more general result by J. L. Rubio de Francia [1] in the setting of locally compact groups. Related issues about differentiation of integrals on the infinite-dimensional torus are also discussed.

Referencias

[1] Rubio de Francia, J. L., Nets of subgroups in locally compact groups. *Comment. Math. Prace Mat.* **20** (1977/78), no. 2, 453–466.

Joint work with Emilio Fernández (Universidad de La Rioja)
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Variations on Gehring's lemma

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Abstract. Gehring's classical lemma states the open ended property of the reverse Hölder classes, and its applications include higher gradient integrability of solutions to uniformly elliptic linear and nonlinear partial differential equations of divergence form. I will discuss a recent work studying variants of this phenomenon: L^2_{loc} valued Hölder continuity in time of solutions to parabolic systems with measurable coefficients, higher integrability of fractional derivatives of solutions to fractional divergence equation as well as functional analytic proof for the linear case of Kuusi–Mingione–Sire higher differentiability theorem for non-local equations.

Joint work with Pascal Auscher, Moritz Egert and Simon Bortz.

Recent progress in sharp Fourier restriction theory

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Abstract. In this talk we will consider some current research problems in sharp Fourier restriction theory. We will discuss the problem of finding sharp constants for restriction estimates, as well as the questions of existence and classification of extremizers of these estimates. The main focus will be on the recent developments related to restriction inequalities for hyperboloids and spheres.

Joint work with Emanuel Carneiro, Diogo Oliveira e Silva, and Betsy Stovall.

John-Nirenberg inequalities and weight invariant BMO spaces

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Abstract. This work explores new deep connections between John-Nirenberg inequalities and Muckenhoupt weight invariance for a large class of BMO-type spaces. The results are formulated in a very general framework in which BMO spaces are constructed using a base of sets, used also to define weights with respect to a non-negative measure (not necessarily doubling), and an appropriate oscillation functional. This includes as particular cases many different function spaces on geometric settings of interest. As a consequence the weight invariance of several BMO spaces considered in the literature is proved. Most of the invariance results obtained under this unifying approach are new even in the most classical settings

Referencias

[1] Jarod Hart and Rodolfo H. Torres, *John-Nirenberg Inequalities and Weight Invariant BMO Spaces*, J. Geom. Anal., to appear, DOI: https://doi.org/10.1007/s12220-018-0054-y.

Joint work with Jarod Hart, YRC Worldwide, Inc.

Algebraic Calderón-Zygmund theory

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Abstract. In this talk, we present Calderón-Zygmund methods for general measure spaces (von Neumann algebras) admitting a Markov semigroup satisfying purely algebraic assumptions. This allows us to construct some sort of 'metric' governing the Markov metric. Our algebraic theory extends Calderón-Zygmund theory in the absence of nice metrics and also yields alternative forms of the theory for classical spaces.

Joint work with Marius Junge, Tao Mei and Javier Parcet
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