Bachelier PhD seminar

March-May 2025, IHP, Paris.

Friday 21th March

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9h-9h20 **Edouard MOTTE**, Catholic University of Louvain.

Title : The Volterra Stein-Stein model with stochastic interest rates

Abstract : We introduce the Volterra Stein-Stein model with stochastic interest rates, where both volatility and interest rates are driven by correlated Gaussian Volterra processes. This framework unifies various well-known Markovian and non-Markovian models while preserving analytical tractability for pricing and hedging financial derivatives. We derive explicit formulas for pricing zero-coupon bond and interest rate cap or floor, along with a semi-explicit expression for the characteristic function of the log-forward index using Fredholm resolvents and determinants. This allows for fast and efficient derivative pricing and calibration via Fourier methods. We calibrate our model to market data and observe that our framework is flexible enough to capture key empirical features, such as the humped-shaped term structure of ATM implied volatilities for cap options and the concave ATM implied volatility skew term structure (in log-log scale) of the S&P 500 options. Finally, we establish connections between our characteristic function formula and expressions that depend on infinite-dimensional Riccati equations, thereby making the link with conventional linear-quadratic models. Joint work with Eduardo Abi Jaber and Donatien Hainaut.

9h20-9h40 **Othmane ZARHALI**, Université Paris Dauphine - CNRS.

Title : From rough to multifractal volatility, topics around the Log S-fBM model.

Abstract : The Log Stationary Fractional Brownian Motion (Log S-fBM) model, introduced by *Peng, Bacry,* and *Muzy* , describes a log-volatility process driven by a stationary fractional Brownian motion (S-fBM). This model is characterized by three key parameters: the intermittency parameter λ, the correlation scale T, and the Hurst exponent H. Notably, as H approaches zero, the model?s multifractal random measure (volatility measure) converges to that of the multifractal random walk introduced by *Bacry et al.*. In contrast, when $H \approx 0.1$, the model captures rough volatility dynamics. A multidimensional extension of the Log S-fBM model, referred to as the m-Log S-fBM was also developed. In this framework, the log-volatilities of multiple assets are correlated, with dependencies governed by both the cointermittency matrix and the co-Hurst matrix. These matrices ensure that the marginal distributions of the model retain the one-dimensional Log S-fBM dynamic. A key analytical tool for studying this model is the small intermittency approximation,

which allows to approximate the generalized moments of the normalized log-volatility over a time period $\Delta > 0$ using the moments of the integrated S-fBM process over the same period when λ^2 is small. This approximation is particularly relevant given the empirical findings of Wu et al., who observed that for various assets, $\lambda^2 \approx 0.02$. Besides, the Log S-fBM model can be used in the Nested factor model, introduced by *Bouchaud et al.*, where the asset return fluctuations are explained by common factors representing the market economic sectors and residuals (noises). These residuals share with the factors a common dominant volatility mode in addition to the idiosyncratic mode unique to each residual. Here, we consider the case of a single factor, where the only dominant common mode is a S-fBM process with Hurst exponent $H \simeq 0.11$, while the residuals, in addition to the previous common mode, contain idiosyncratic components with Hurst exponents $H \simeq 0$. Furthermore, we propose a statistical procedure to estimate the Hurst factor exponent from stock return dynamics, providing theoretical guarantees. The method performs well in the limit where the number of stocks N tends to infinity. In this talk, we introduce the Log S-fBM model in its one-dimensional and multidimensional forms, present the calibration procedure based on the small intermittency approximation, and discuss the Nested Log S-fBM factor model. This is a joint work with Cécilia Aubrun, Emmanuel Bacry, Jean-Philippe Bouchaud, Jean-François Muzy.

9h40-10h **Yadh HAFSI**, Université Paris-Saclay, LaMME.

Title : Optimal Execution under Incomplete Information

Abstract : We study optimal liquidation strategies under partial information for a single asset within a finite time horizon. We propose a model tailored for high-frequency trading, capturing price formation driven solely by order flow through mutually stimulating marked Hawkes processes. The model assumes a limit order book framework, accounting for both permanent price impact and transient market impact. Importantly, we incorporate liquidity as a hidden Markov process, influencing the intensities of the point processes governing bid and ask prices. Within this setting, we formulate the optimal liquidation problem as an impulse control problem. We elucidate the dynamics of the hidden Markov chain's filter and determine the related normalized filtering equations. We then express the value function as the limit of a sequence of auxiliary continuous functions, defined recursively. This characterization enables the use of a dynamic programming principle for optimal stopping problems and the determination of an optimal strategy. It also facilitates the development of an implementable algorithm to approximate the original liquidation problem. We enrich our analysis with numerical results and visualizations of candidate optimal strategies.

10h-10h20 **Break**

10h20-10h40 **Fallou NIAKH** , ENSAE IP Paris, CREST

Title : P2P Risk Basis management for renewable production parametric insurance

Abstract : This work presents a framework for peer-to-peer (P2P) risk basis management applied to solar electricity generation. The approach leverages physically based simulation models to estimate the day-ahead production forecasts and the actual realized production at the solar farm level. We quantify the financial loss from mismatches between forecasted and actual production using the outputs of these simulations. The framework then implements a parametric insurance mechanism to mitigate these financial losses and combines it with a P2P market structure to enhance participant risk sharing. By integrating day-ahead forecasts

and actual production data with physical modeling, this method provides a comprehensive solution to manage production variability, offering practical insights for improving financial resilience in renewable energy systems. The results highlight the potential of combining parametric insurance with P2P mechanisms to foster reliability and collaboration in renewable energy markets

10h40-11h **Hamza BODOR**, Centre d'économie de la Sorbonne.

Title : Deep Learning Meets Queue-Reactive: A Framework for Realistic Limit Order Book Simulation.

Abstract : The Queue-Reactive model introduced by Huang et al. (2015) has become a standard tool for limit order book modeling, widely adopted by both researchers and practitioners for its simplicity and effectiveness. We present the Multidimensional Deep Queue-Reactive (MDQR) model, which extends this framework in three ways: it relaxes the assumption of queue independence, enriches the state space with market features, and models the distribution of order sizes. Through a neural network architecture, the model learns complex dependencies between different price levels and adapts to varying market conditions, while preserving the interpretable point-process foundation of the original framework. Using data from the Bund futures market, we show that MDQR captures key market properties including the square-root law of market impact, cross-queue correlations, and realistic order size patterns. The model demonstrates particular strength in reproducing both conditional and stationary distributions of order sizes, as well as various stylized facts of market microstructure. The model achieves this while maintaining the computational efficiency needed for practical applications such as strategy development through reinforcement learning or realistic backtesting.

Friday 28th March

9h-9h20 **Antoine LOTZ**, Université Paris Dauphine & EDF Lab

Title: A central limit theorem for locally stationary Hawkes processes

Abstract : We prove a law of large numbers and functional central limit theorem for a class of multivariate Hawkes processes with time-dependent reproduction rate. We address the difficulties induced by the use of non-convolutive Volterra processes by recombining classical martingale methods introduced in Bacry et al. (2013) with novel ideas proposed by Kwan, Chen and Dunsmuir (2024). The asymptotic theory we obtain yields useful applications in financial statistics. As an illustration, we derive closed-form expressions for price distortions under liquidity constraints, and present some first estimations of the model on order book data from intraday power markets.

9h20-9h40 **Elie ATTAL**, CMAP, Ecole Polytechnique.

Title: From Hyper Rougness to Jumps as $H \to -1/2$.

Abstract: We investigate the weak limit of the hyper-rough square-root process as the Hurst index H goes to $-1/2$. This limit corresponds to the fractional kernel $t^{H-1/2}$ losing integrability. We establish the joint convergence of the couple (X, M), where X is the hyper-rough process and M the associated martingale, to a fully correlated Inverse Gaussian Lévy jump process. This unveils the existence of a continuum between hyper-rough continuous models and jump processes, as a function of the Hurst index. Since we prove a convergence of continuous to discontinuous processes, the usual Skorokhod J_1 topology is not suitable for our problem. Instead, we obtain the weak convergence in the Skorokhod M_1 topology for X and in the non-Skorokhod S topology for M.
Based on a joint work with Eduardo Abi Jaber (CMAP) and Mathieu Rosenbaum (CMAP).

9h40-10h **Lamia LAMRANI**, Université Paris-Saclay, CentraleSupélec.

Title : Holdout method error and optimal split for large covariance matrix estimation

Abstract : Covariance matrix estimation is an important topic for financial applications such as risk management or portfolio selection. Cross-validation, one of the most widely used methods for model selection and evaluation, can be used to improve large covariance matrix estimation. However, although its efficiency is recognized for financial applications, little is known about the theoretical behavior of its error. In this talk, we discuss the expected Frobenius error of the holdout method, a particular cross-validation procedure that involves a single train and test split, for a generic rotationally invariant multiplicative noise in the high dimension limit. When the population covariance matrix follows an inverse Wishart distribution, we find a closed form for the expected holdout error. Furthermore, we find that the optimal train-test split ratio is proportional to the square root of the order of the matrix to estimate.

10h20-10h40 **Thomas PEYRAT**, CREST-IMT-Exiom Partners.

Title : A Multivariate Self-Exciting Processes with Dependencies for actuarial applications

Abstract : The compound Poisson process is commonly used to model the loss process associated to a certain risk. This process relies on the assumption of independence between the counting process (a Poisson

process) and the claim sizes (independent and identically distributed random variables), making the calculation of the expectation and correlation straightforward. However, these assumptions limit its applicability to more complex risk structures. To overcome these limitations, we propose a similar framework in which the counting process is replaced by a self-exciting process whose intensity is influenced by the amount of the claims. Introducing dependency between the counting process and the claims, however, induces theoretical challenges in the computations of the first two moments of the loss process. To this end, we introduce the class of Multidimensional Self-Exciting Processes with Dependencies (MSPD), for which we derive closed-form expressions for the expectation and correlation.

10h40-11h **Benoît ORIOL**, CEREMADE and Société Générale.

Title : Non-linear shrinkage of weighted sample covariances.

Abstract : Covariance estimation is a central topic in multivariate analysis, and the weighted sample covariance emerges as a natural candidate to estimate it in finance. However, in high dimension, due to spectral deformation, the eigenvalues of the weighted sample covariance need to be unbiased in order to make the estimation optimal. We compute the asymptotic non-linear shrinkage formulas that correct the spectrum of weighted sample covariance, in the spirit of Ledoit and Péché. We detail explicitly the formulas for exponentially-weighted sample covariances, and propose an algorithm to compute them.