The (unfortunate) complexity of the economy

15 years of 'Econophysics': a personal view*

see: Nature (30 Oct 2008)
& Physics World (April 2009)

J.P. Bouchaud, Capital Fund Management

*Note: arXiv/q-fin since Dec. 2008; ca. 1000 papers

The Sacred Cows of Theoretical Economics...

- We are asked to believe that, as a good working hypothesis for human behaviour:

- Agents are infinitely rational, their decisions result from maximizing a utility function

- All possible future states of the world are known, with their probabilities: Risk but no radical uncertainty (J. M. Keynes)

- Markets are in "equilibrium": prices are such that supply meets demand, (nearly) instantaneously.

The Sacred Cows of Theoretical Economics

- $\longrightarrow$ Efficient market theory: Market prices reflect faithfully the Fundamental Value of assets and only move because of exogeneous unpredictable news.

- Mechanism: Any error or mispricing would be arbitraged away by informed rational agents and disappears (??)

- Platonian markets which merely reveal fundamental values without influencing them – or is it a mere tautology??

The Sacred Cows of Theoretical Economics

- In the extreme incarnation of EMT, prices should move with no, or very little trades – barring silly noise traders

- Crashes can only be exogenous, not induced by markets dynamics itself – oh really??

...with serious political consequences

- Markets allow optimal allocation of resources, including human (??)
- A rational theory of unemployment, drug addiction, etc.
- Any constraint ("imperfection") drives the market *away* from efficiency $\longrightarrow$ deregulation (??)

The Aftermath

- *Those of us who have relied on the self-interest of lending institutions, myself included, are in a state of shocked disbelief...Yes, I've found a flaw [in the theory]. I don't know how significant or permanent it is. But I've been very distressed by that fact.*

  Alan Greenspan, October 2008 (!!!)

- *Do you guys really believe that?*

  Phil Anderson, Santa Fe, 1987 (The first econophysics meeting)

More Sacred Cows – Mathematical Finance

- The Black-Scholes theory of options: Prices can be modelled as a Geometric Brownian Motions $\longrightarrow$ zero risk hedge (??)

- An option is an insurance on the future movements of a stock, currency, oil, etc.

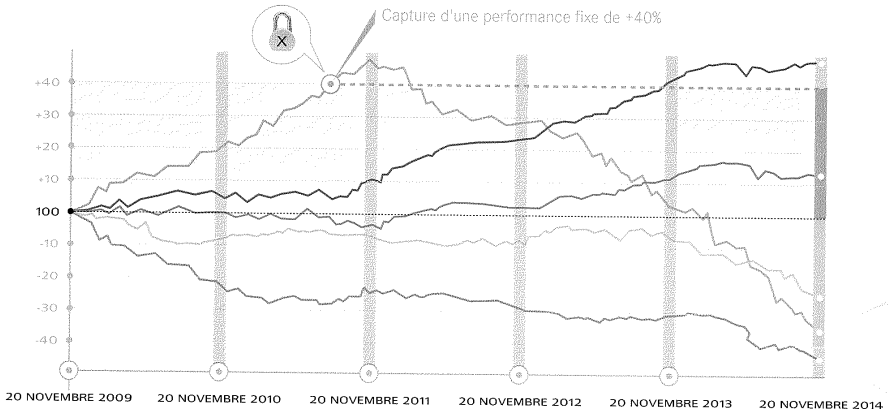
- Zero Risk + the Absence of Arbitrage opportunities principle $\longrightarrow$ unique price for the option

- Stock markets allow one to be bet on the average price change, option markets on the variance !

LCL CAPTURE 40 et LCL CAPTURE 40 VIE sont des Fonds Commun de Placement dont la performance à l'échéance de la formule dépend de l'évolution du DJ Euro Stoxx 50 (hors dividende). Cet indice regroupe les 50 plus grosses capitalisations boursières de la zone Euro.

FONDS STRUCTURÉS

LCL CAPTURE 40
LCL CAPTURE 40 VIE



Courbes d'évolutions fictives destinées uniquement à illustrer le mécanisme de remboursement à l'échéance du fonds.
Ces chiffres sont donnés à titre indicatif. Ils ne préjugent en rien de l'évolution du DJ Euro Stoxx 50.

5 HYPOTHÈSES

DE VALORISATION DE VOTRE INVESTISSEMENT EN FONCTION DE L'ÉVOLUTION DU DJ EURO STOXX 50 (HORS DIVIDENDE).

HYPOTHÈSE 1

Si la performance du DJ Euro Stoxx 50 (hors dividende) est supérieure ou égale à 40%[1] à l'échéance ou en cours de vie, **vous bénéficiez d'une performance fixe de +40%[1] (soit un rendement annuel de 6,96%).**

HYPOTHÈSE 2

Si la performance du DJ Euro Stoxx 50 (hors dividende) est comprise entre 0 et +40%[1] à l'échéance et si elle n'a jamais dépassé les 40%[1] en cours de vie, **vous bénéficiez de l'intégralité de la performance de l'indice.**

HYPOTHÈSE 3

Si la performance du DJ Euro Stoxx 50 (hors dividende) est comprise entre 0 et -40%[1] à l'échéance et si elle n'a jamais dépassé les 40%[1] en cours de vie, **votre capital est protégé.**

HYPOTHÈSE 4

Dès que l'indice DJ Euro Stoxx 50 (hors dividende) franchit au moins une fois +40%[1] en cours de vie, quelle que soit l'évolution ultérieure de l'indice, **vous bénéficiez d'une performance fixe de +40%[1] (soit un rendement annuel de 6,96%).**

HYPOTHÈSE 5

Si la performance du DJ Euro Stoxx 50 (hors dividende) est inférieure à -40%[1] à l'échéance et si elle n'a jamais dépassé les +40%[1] en cours de vie, **votre investissement subit une perte en capital égale à la baisse de l'indice.**

I. Methodological issues/Resistance to change

- Theoretical economists tend to prefer proving theorems and are suspicious of exploratory numerical simulations

  Done properly, computer simulation represents a kind of telescope for the mind, multiplying human powers of analysis and insight just as a telescope does our powers of vision

  Marc Buchanan, This Economy does not Compute, October 2008 (NY Times)

- Is it really better to stick with the implausible but rigourous theory of perfectly rational agents rather than to venture into modelling the infinite number of ways agents can be irrational?

- *These concepts are so strong that they supersede any empirical observation* – Anonymous referee

I. Methodological issues/Resistance to change

- Economics/Financial engineering over-mathematized: more emphasis on axioms/equations than on intuition/mechanisms, partially responsible (in my view) for the current crisis

- *As I see it, the economics profession went astray because economists, as a group, mistook beauty, clad in impressive-looking mathematics, for truth.*

  Paul Krugman, How Did Economists Get It So Wrong, September 2009 (NY Times)

- *Research tended to be motivated by the internal logic (...) and esthetic puzzles of established research programmes rather than by a powerful desire to understand how the economy works - let alone how the economy works during times of stress and financial instability.*

  Willem Buiter, The unfortunate uselessness of most state of the art academic monetary economics, March 2009

Some empirical facts

- Financial markets offer Terabytes of information (weekly) to try to investigate why prices move

- A) Are news really the main determinant of volatility? Exogenous vs. endogenous dynamics

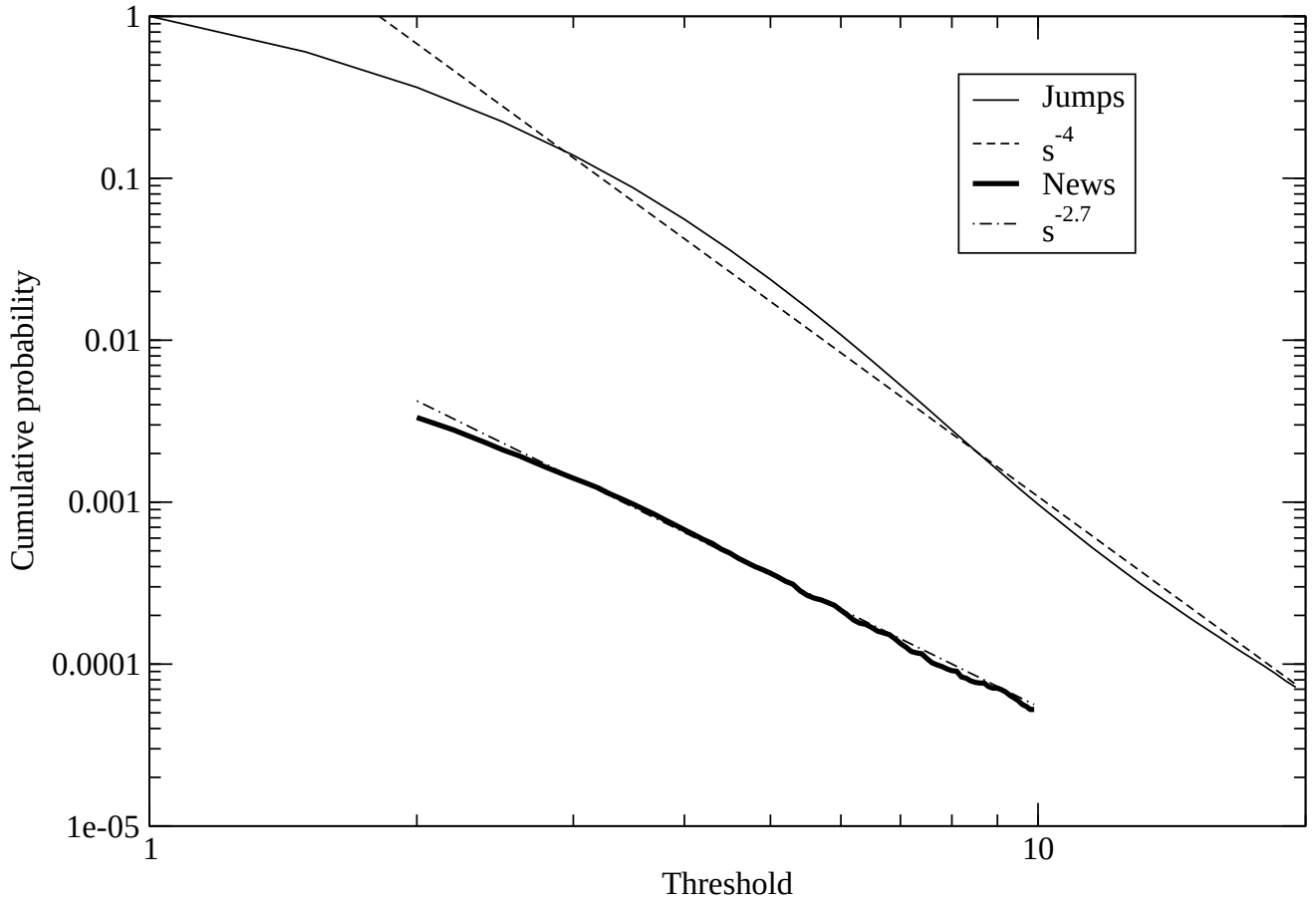
- B) Are price really such that supply instantaneously equals demands? How fast information is included in prices?

II-A. Exogenous or endogenous dynamics?

- Yes, some news make prices jump, sometimes a lot, but jump freq. is much larger than news freq.

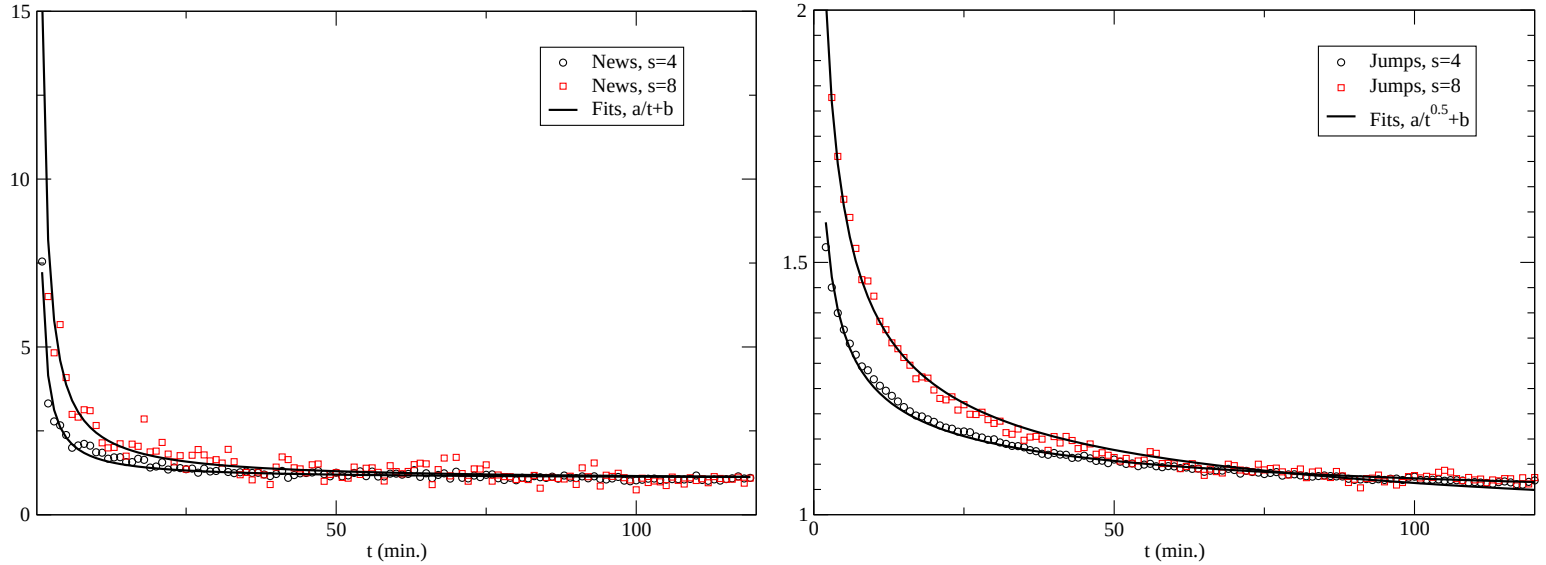
- On stocks, only $\sim 5\%$ of $4-\sigma$ jumps can be attributed to news, most jumps appear to be endogeneous

- Different statistics: return distributions and 'aftershocks' (volatility relaxation)



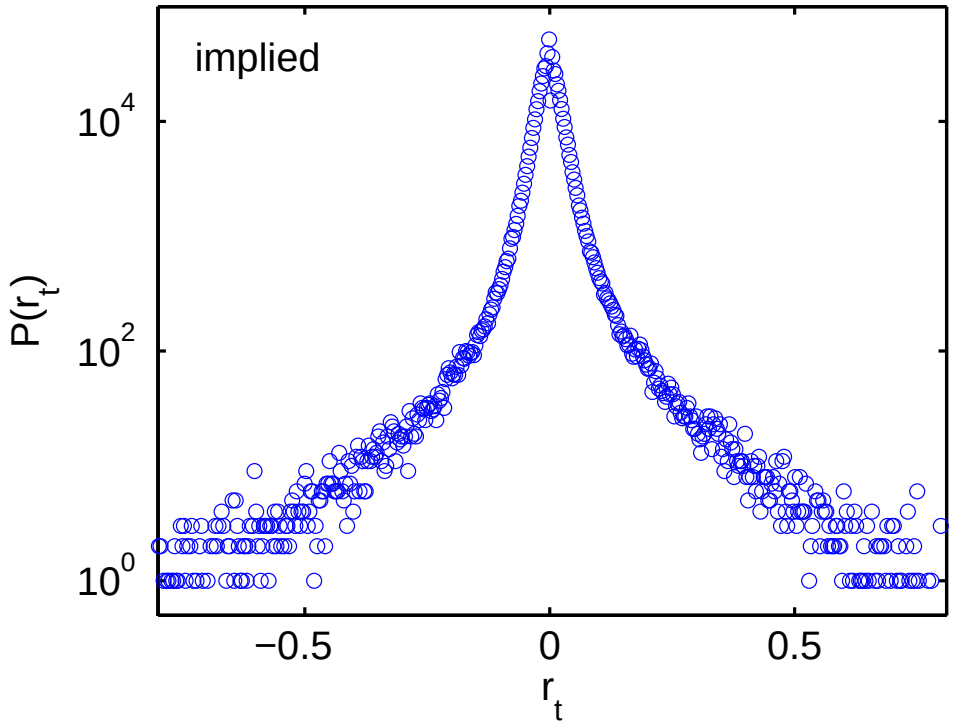
Power-law distribution of news jumps and no-news jumps. With A. Joulin, D. Grunberg, A. Lefevre

Two jump types: Aftershocks



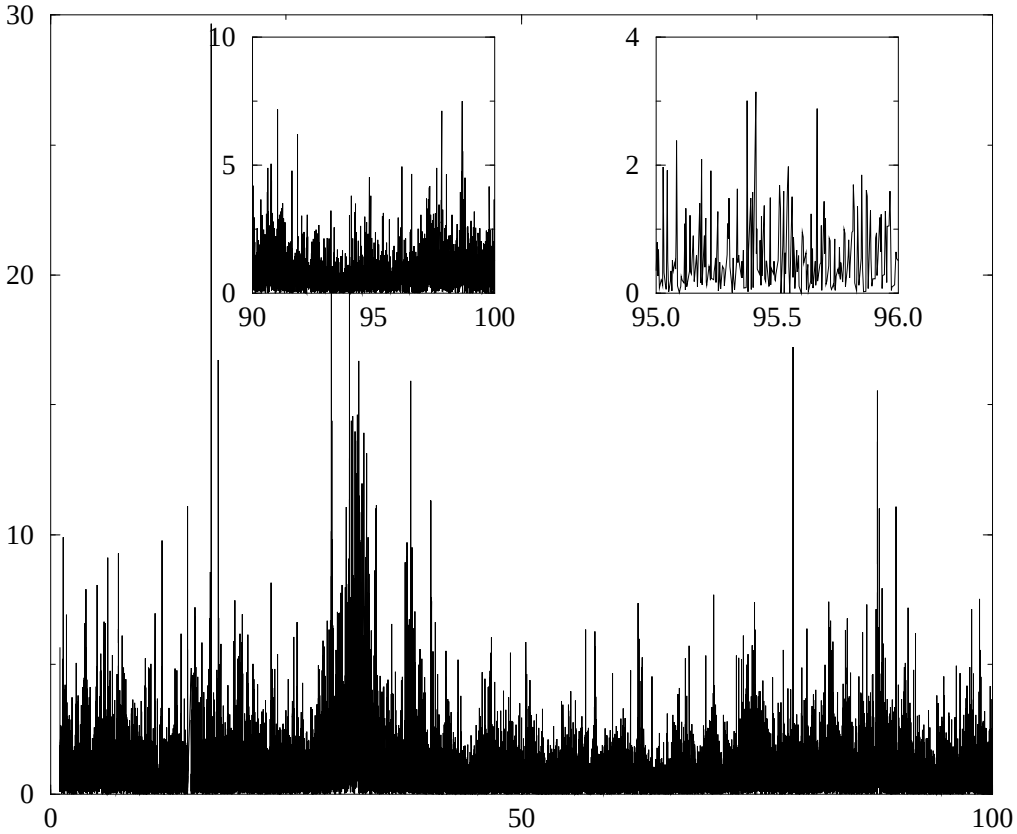
Volatility relaxation after news (t^{-1}, left) and endogenous jumps ($t^{-1/2}$, right). With A. Joulin, D. Grunberg, A. Lefevre

Power-law tails



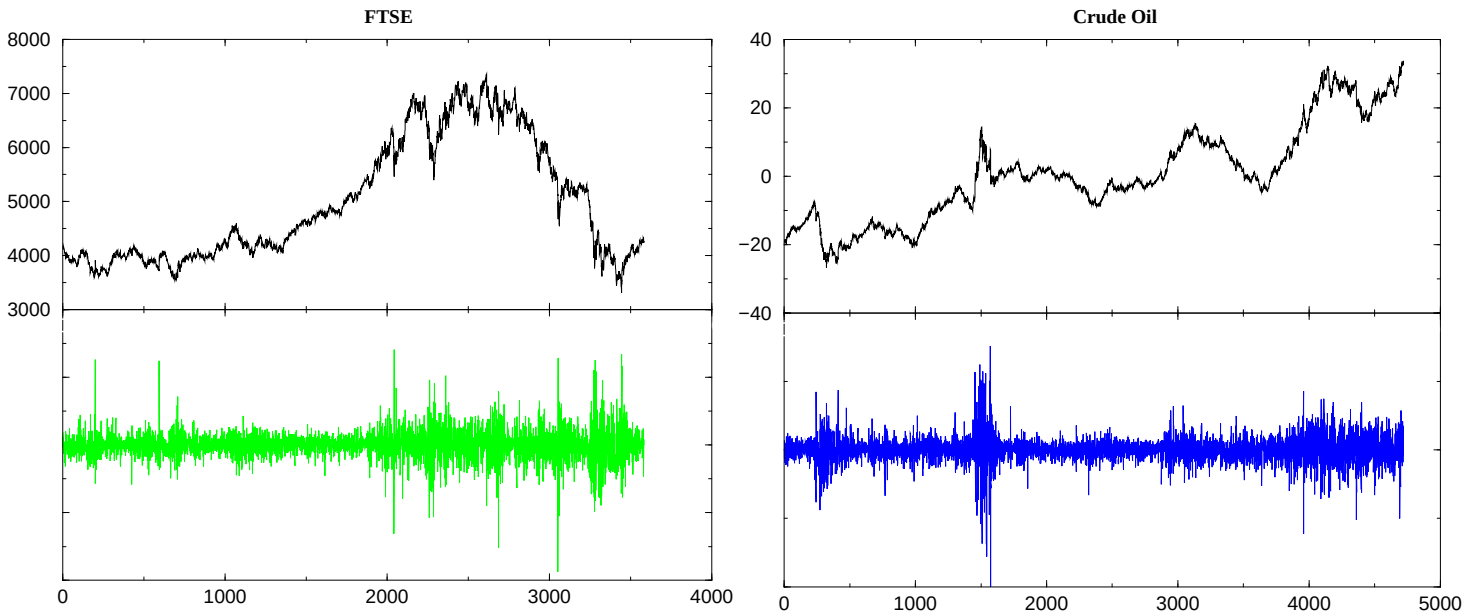
Power-law distribution of daily volatility moves on option markets or *any other traded stuff*

Multiscale intermittency



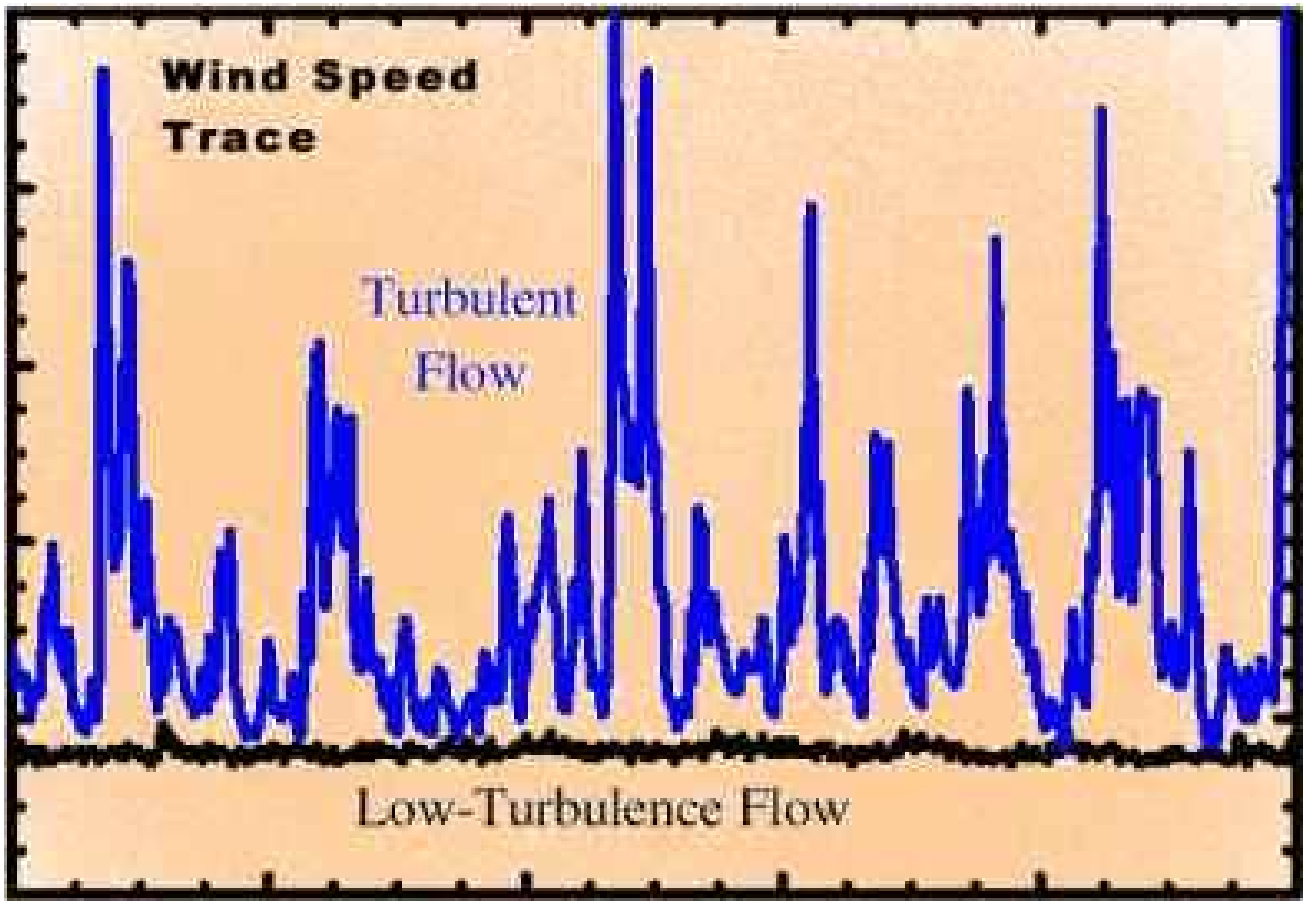
Excess volatility, with long range memory

Other examples



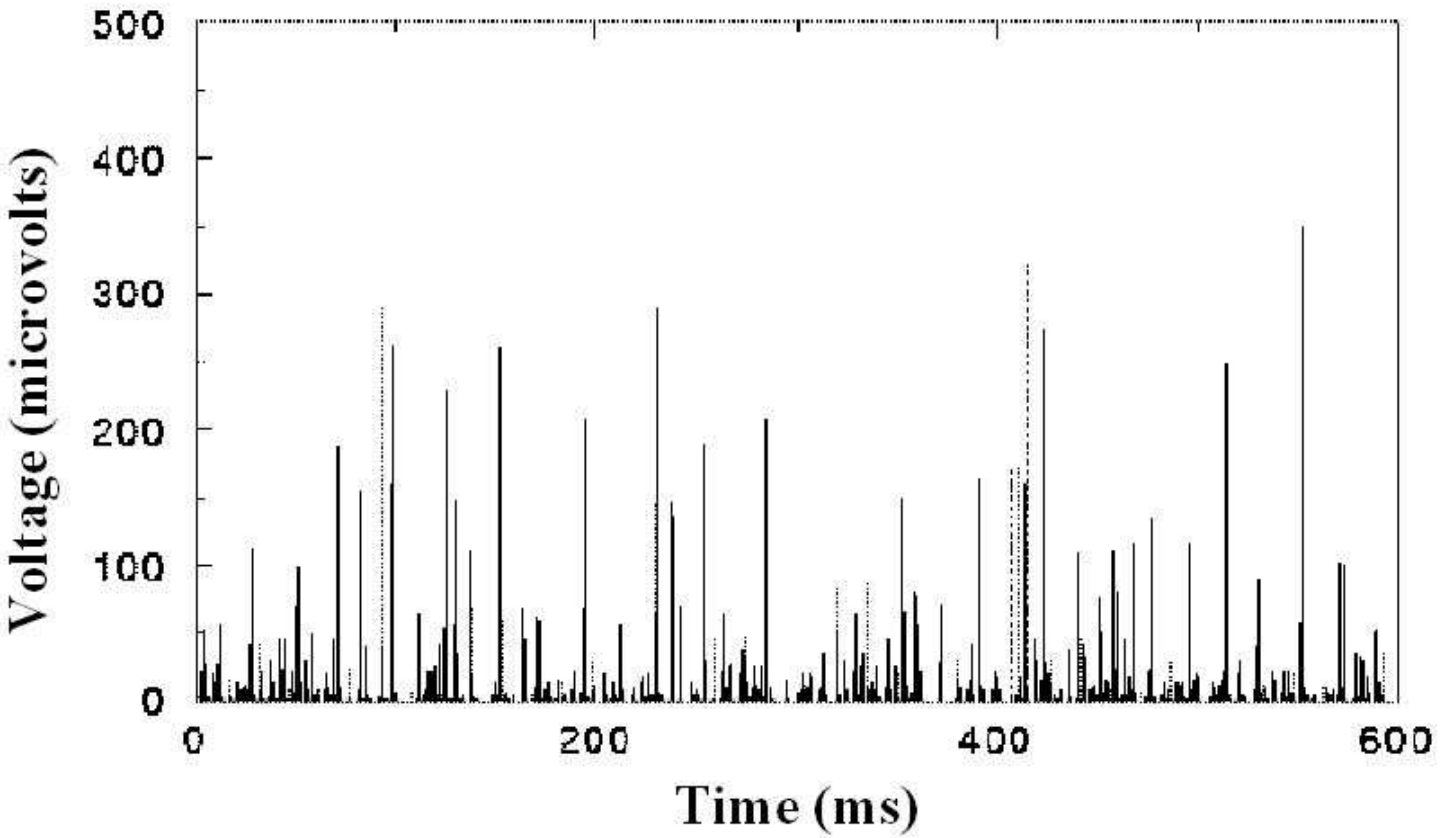
– looks a lot like endogeneous noise in complex systems (turbulence, Barkhausen noise)

Turbulence: intermittency



Local dissipation in a turbulent flow

Barkhausen noise



Slow, regular and featureless exogeneous drive but intermittent endogeneous dynamics

II. Questions with possible empirical answers

- A. Are news the main determinant of volatility?: clearly no
- B. Are price such that supply instantaneously equals demands? How fast information is included in prices?

II-B. Are markets in "equilibrium?"

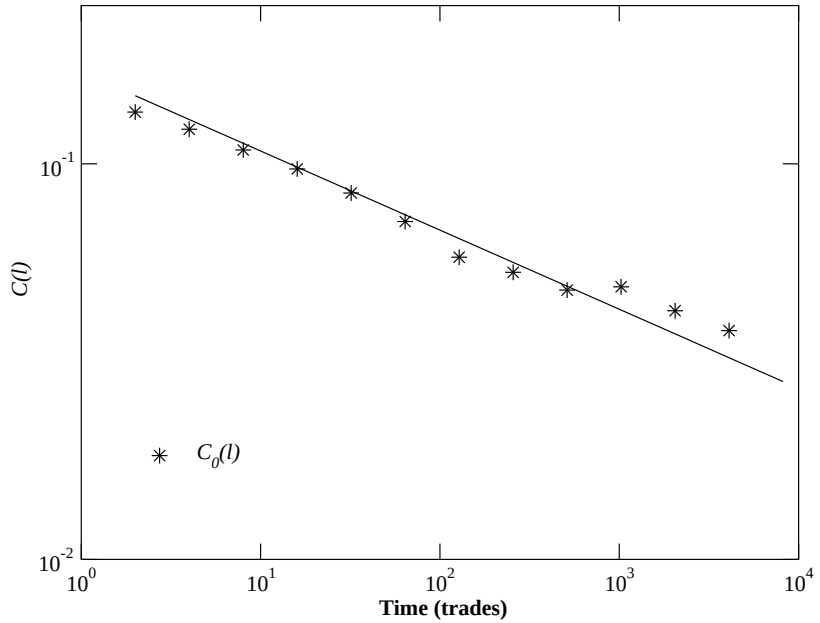
- UHF data allows one to understand the microscopics of order flow and price formation

- One can distinguish buy orders from sell orders

- Surprise: the autocorrelation of the sign of trades is long-range correlated $C(\tau) \sim \tau^{-\gamma}$, $\gamma < 1$, over several days or weeks

- A Paradox: Sign of order flow very predictable and orders impact the price – but no predictability in the sign of price changes ??

Trade correlations



Correlations extend to several days! (Chordia et al., Hopman, etc.)

II-B. Are markets in "equilibrium?"

- Even "liquid" markets offer a very small immediate liquidity (10^{-5} for stocks) – buyers/sellers have to fragment their trades over days, weeks or even months

- "Information" can only be *slowly incorportated into prices*, latent demand does not match latent supply – Markets are hide and seek games between buyers and sellers and are *not* in equilibrium

- Critical long term market resiliency: the impact of a trade decays as a power-law as to offset exactly the trade correlation (with J. Kockelkoren, M. Potters, M. Wyart)

II- Conclusion

- A) Are news really the main determinant of volatility?
  - No, endogenous dynamics more likely, through impact – see below
- B) Are price really such that supply instantaneously equals demands?
  - No, "information" is only very slowly incorportated into prices

III. Some important missing ingredients

- A. Imperfect Rationality: noisy decisions but not necessarily of strong distortions
- B. Interaction and Heterogeneity The Random Field Ising Model, Spin-Glasses
- C. Impact and feedback loops Model induced crashes
- Conclusion: Uncertainty ?

III-A. Models of imperfect rationality

- Agents do make errors and have regrets (cognitive or sensorial biases, imperfect information, urgency, negligence, algorithmic complexity) and may choose suboptimal solutions

- Tendency to prefer a better solution by comparing nearby choices, leading to a statistical mechanics of choices

- Source of errors but not necessarily of strong distortions

III. Some important missing ingredients

- A. Imperfect Rationality
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III-B. Models of collective decisions

- Collective behaviour is often irreducible to individual dynamics – at variance with the "representative agent theory"

- People do not make decision in isolation but rely on the choice of others: this is a fact of life...

- Many important situations in practice: vaccines, hygiene, driving, crime, etc.

- Sometimes very strong distortion/amplification phenomena due to imitation (Louis XIV's wig)

Starlings in Rome

A. Cavagna et al.

III-B. Models of collective decisions

- Binary decision of agent i: $S_i = \pm 1$ (to buy/sell/lend or not to buy/sell/lend, to join or not to join a riot, etc.)

- Influence factors:
  - personal opinion, propensity or utility ϕ_i – heterogeneous with probability P
  - public information (price, technology level, zeitgeist) $F(t)$, smooth
  - social pressure or imitation effects $\sum_j J_{ij} S_j$

III-B. Models of collective decisions

- The RFIM update rule:

$$S_i(t) = \text{sign}\left[\phi_i + F(t) + \sum_{j \in \mathcal{V}_i} J_{ij} S_j(t-1)\right],$$

- Aggregate demand: $\mathcal{O} = N^{-1} \sum_i S_i$

- Applications: Birth rates, Cell phones, Clapping...(with Q. Michard)

III-B. Model of collective decisions

- $J < J_c$: personal choices dominate, smooth demand curve

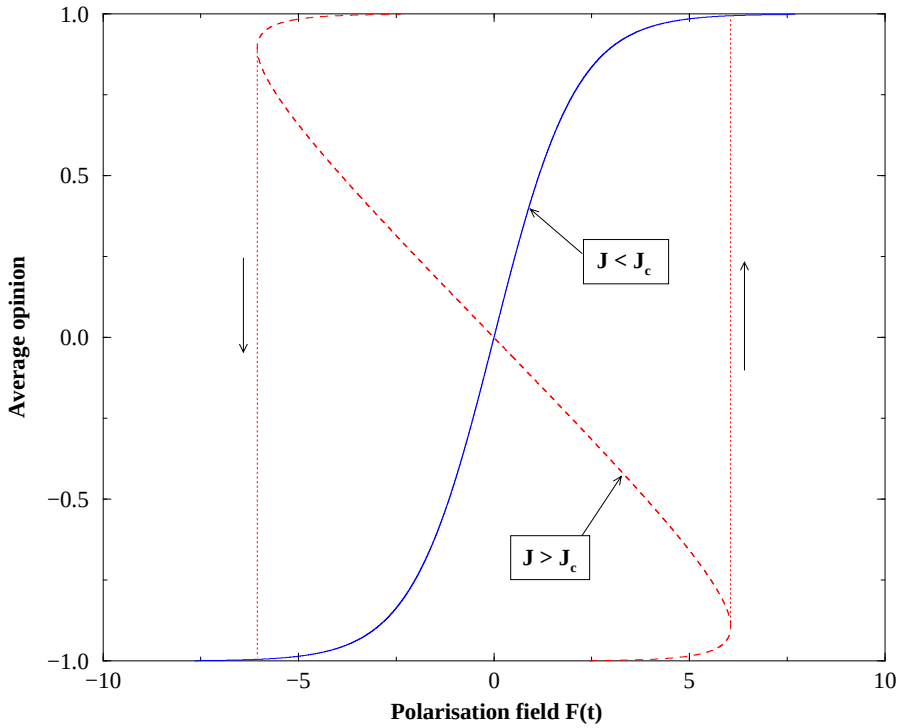
- $J > J_c$: herding dominates, strong deformation of the fundamental demand curve: discontinuities appear at the macro level – imitations induced panic/crashes

- $J \approx J_c$: avalanche dynamics with power-law distribution of sizes

- Example: Clapping, but also Contagion: Pessimism, Trust, Default, etc.

- Hysteresis in and out of the crisis

III-B. Model of collective decisions



Breakdown of the representative agent theory – cf. Alan Kirman: *Whom or what does the representative individual represent?*

III-B. Metaphoric models of complexity

- Generically, a system such that individual elements are heterogeneous and interacting (competing) is in the "spin-glass" class of problems (cf. P.W. Anderson, 1987) – cf also pinned domain walls, vortices, fracture fronts, etc.:
  - Many metastable states
  - Slow intermittent dynamics, never in equilibrium – cf. glasses
  - Fragility to external perturbations

- New methods from physics to deal with these problems – "cavity" theory (1985 $\rightarrow$ 2009)

III. Some important missing ingredients

- A. Imperfect Rationality
- B. Interaction and Heterogeneity
- C. Impact and feedback loops Model induced crashes
- Conclusion: Uncertainty ?

III-C. Impact and feedback loops

- Impact of trades is crucial to understand why prices move
- The price process is not God given and we merely observe it, tracking the "true" value
- Even "liquid" markets are not that liquid (cf. above)
- Trading, even uninformed and with relatively small volumes, strongly influences prices and leads to noticeable effects or even positive feedback loops

III-C. Impact and feedback loops

- Example: Portfolio Insurance & the 1987 crash
- Remember the Black-Scholes model: zero risk means perfect replication
- Forget buying a true insurance protecting against a fall of the market: follow the replicating strategy
- Sell when the market goes down!
- LOR: 80 B$ "insured" like that in 1987 – for a daily market liquidity of 5 B$....

III-C. Impact and feedback loops

- Example: Portfolio Insurance & the 1987 crash
- This did not cause the crash but amplified it tremendously
- By neglecting the crash probability, B&S contributed in creating one!
- After 1987: very slow, incomplete evolution away from Black & Scholes – still the textbook standard, with very little caveats.
- Cf. *Les marchés dérivés: pour une pédagogie du risque*, JPB, Le Monde, Mars 1995.

III-C. Impact and feedback loops

- History repeating: Credit Derivatives & the 2008 crash

- Absurd models for correlation between obligors $\longrightarrow$ Huge underestimation of the risk of credit derivatives (CDOs, etc)

- Feedback loops: a) Mark to market accounting rules – inspired by efficient market theory; b) CDSs

- Lost of confidence in the models $\longrightarrow$ overreaction and unjustified write-downs $\longrightarrow$ Banks technically bankrupt (Lehmann)

- By neglecting global systemic risk, faulty models created it

Conclusion

- Primary importance of data and orders of magnitude over axioms and theorems, mechanisms over equations

- Markets are complex systems that generate rich endogenous dynamics

- Interesting metaphoric models from physics with interactions and heterogenities that lead to fragility, discontinuities and intermittency

- Need to identify interactions and feedback loops to prevent contagion and instability (models & rules can destabilize the market) – need for "second generation" models

Uncertainty and Black-Swans

- How to foster a real engineering of the economy? Agent Based Simulations with millions of realistic agents – cf. D. Farmer, D. Foley, Nature August 2009

- How to model what seems beyond modelling and reduce the realm of uncertainty and "Black Swans"? (N. Taleb)

- A major scientific program