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                                 ________________________________________________
HIV-1 Vpr          MEQAP---EDQGPQREPYNEWTLELLEELK?EAVRHFPRIWLHSLGQHIYET---
HIV-2 Vpr      MTEAPTE?PP---EDE?PQREPWDEWV?EVLEEIKEEALKHFDPRLL?ALGNYIY?R---
HIV-2 Vpx       MTDPRERVPPGNSGEETIGEAF?-WLDRTVEEINR?AVNHLPRELIFQVWQRSW?YWHD
SIVagm Vpr    MASGRDPRE??PGWLEIWDL?REPWDEWLRDML?DLNQEA??HFGRNLLFRVWNYCVEEG?R
                   ****  *     *    *    **    ****  ** * ** * * ***

                ____________________________
HIV-1 Vpr     -YG-DTWEGVEAIIRILQQLLFIHFRIGCQHSR------IGITRQRRARNGS--SRS
HIV-2 Vpr     -HG-DTLEGARELIRILQRALF?HFRAGC?HSR------IGQ?GGGNPLSAIPPSRGMQ
HIV-2 Vpx     EQGMS?SYTKYRYLCLMQKAMF?H?KKGCRCLG-------GGHGPGGWRPGPPPPPPPGLA
SIVagm Vpr    -?G?P??E??YKYYRIVQKALFVHFRCGCRRR?PF?PYEERR?GQGGG?A???---PPGL
                *       * *    *** * *   ***          *   * **   * **   ****
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FIG. 2 Alignment of consensus Vpr and Vpx sequences of HIV-1, HIV-2 and $SIV_{AGM}$. Bold asterisk, residues conserved across all four sequences; asterisk, residues conserved between HIV-2 Vpx and (at least) one other sequence. Residues highlighted in bold in the HIV-2 Vpx sequence are sites where the three other sequences are identical, and may represent adaptive changes (see text). The overlined regions were used for the phylogenetic analyses (Fig. 1*b*).

*vpx* and $SIV_{AGM}$ is not explained.

In fact, the tree (Fig. 1*b*) strongly suggests that the *vpx* gene in $SIV_{SM}$/HIV-2 did indeed appear after the divergence from other primate lentiviruses, but by acquisition of the $SIV_{AGM}$ *vpr* gene (Fig. 1*a*) rather than by duplication of $SIV_{SM}$/HIV-2 *vpr*. This would have required recombination between the ancestral $SIV_{SM}$ and $SIV_{AGM}$ lineages, which could only have occurred if a single monkey was coinfected with both viruses. African green monkeys (of the sabaeus subspecies) and sooty mangabeys share habitats in West Africa, and we have previously reported evidence of recombination between their viruses[3], involving the replacement of the 3′ *gag* and 5′ *pol* genes in $SIV_{AGM}$sab with the corresponding regions from an ancestral $SIV_{SM}$. The event proposed here is quite distinct, in that we are invoking the addition of a gene to an ancestral $SIV_{SM}$ by non-homologous recombination. Taken at face value, the tree would suggest that the donor was an ancestral $SIV_{AGM}$. However, the position of $SIV_{AGM}$sab on the same branch as $SIV_{AGM}$ver and $SIV_{AGM}$gri is not strongly supported; in some analyses $SIV_{AGM}$sab was found to switch positions to the $SIV_{SM}$/HIV-2 lineage. Thus, the source of the *vpx* gene could have been $SIV_{AGM}$sab.

Changes in the HIV/SIV genome structure (rearrangement or addition of genes) are usually detrimental to viral replication, yet it is implicit in the above that the recombinant $SIV_{SM}$ must have replaced the existing virus in sooty mangabeys, suggesting that a selective advantage may have been conferred by the additional gene. Whereas HIV-1 needs both Vpr and the *gag*-encoded matrix nuclear localization domain to establish a productive infection in terminally differentiated macrophages[9], $SIV_{SM}$ appears to require only Vpx[8]. Thus, through the acquisition of the $SIV_{AGM}$ *vpr* gene, $SIV_{SM}$ may have been able to replicate more efficiently in non-dividing target cells (for example, Langerhans cells in the mucosa) and achieve enhanced transmissibility. (There could be other advantages to having two proteins with specialized functions.) Branch lengths in the tree suggest that *vpx* evolved very rapidly after acquisition. This was probably not due to relaxation of selective constraints, since the rates of evolution of *vpx* and *vpr* are now similar (judged by the diversity within $SIV_{SM}$/HIV-2), but may reflect an initial period of adaptation of *vpx* to a new role in $SIV_{SM}$.

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# Turbulence and financial markets

SIR — Ghashghaie *et al.* discuss analogies between the price dynamics in the foreign exchange market and three-dimensional fully developed turbulence[1]. We have independently carried out a study comparing the dynamical properties of the S&P 500 index and of the time evolution of a three-dimensional fully turbulent fluid, but we draw different conclusions. Specifically, we find that although intermittency — abrupt changes of activity in the time evolution of the variance of price changes and of the mean energy dissipation — and non-gaussian behaviour (for short times) in the probability distribution of price and velocity changes characterize both systems, the stochastic nature of the two processes is quantitatively different.

Among the differences we find are: first, price changes of the S&P 500 are substantially uncorrelated (we detect only a slightly enhanced diffusion), but velocity changes in three-dimensional turbulence are anticorrelated. Specifically, we find that the measured autocorrelation function of the price changes is a fast-decaying monotonic function with a characteristic time of a few minutes and the spectral density of the index is a power-law $S(f) \propto f^{-2}$ for more than four orders of magnitude, but in three-dimensional turbulence an inertial range $S(f) \propto f^{-5/3}$ exists (Fig. 1).

Second, the maximum of the probability distribution $P(Z = 0)$ of price changes $Z_{\Delta t}(t)$ after a time $\Delta t$ shows clear Lévy (non-gaussian) scaling (for $1 \leq \Delta t \leq 1{,}000$ minutes) as a function of $\Delta t$ (ref. 2), but the corresponding turbulence quantity does not show scaling (Fig. 2).

One interesting result presented in ref. 1 is that the distribution of price changes in the foreign exchange market is changing shape as a function of the time delay $\Delta t$. The distribution evolves from a leptokurtic (with tails fatter than in a gaussian distribution) to a gaussian shape. Although a similar behaviour is observed in fully developed turbulence, the deep difference observed in the correlation (of price and velocity changes) and scaling (of the central part of the respective distributions) properties of the two processes leads us to conclude that indeed, at the moment, the simplest model describing the main features of the dynamics of prices in speculative markets is the truncated Lévy flight (TLF) introduced in refs 2–4.

In this model, independent identically distributed price changes are characterized by a Lévy stable distribution in the central part of the distribution, but a cut-off is present after which the distribution is not power-law. This truncation implies that the process is characterized by a finite variance. A TLF is only roughly self-similar and the process eventually converges to a gaussian distributed process due to the finiteness of the variance, as predicted by the central limit theorem. The TLF also describes quite well the dynamics

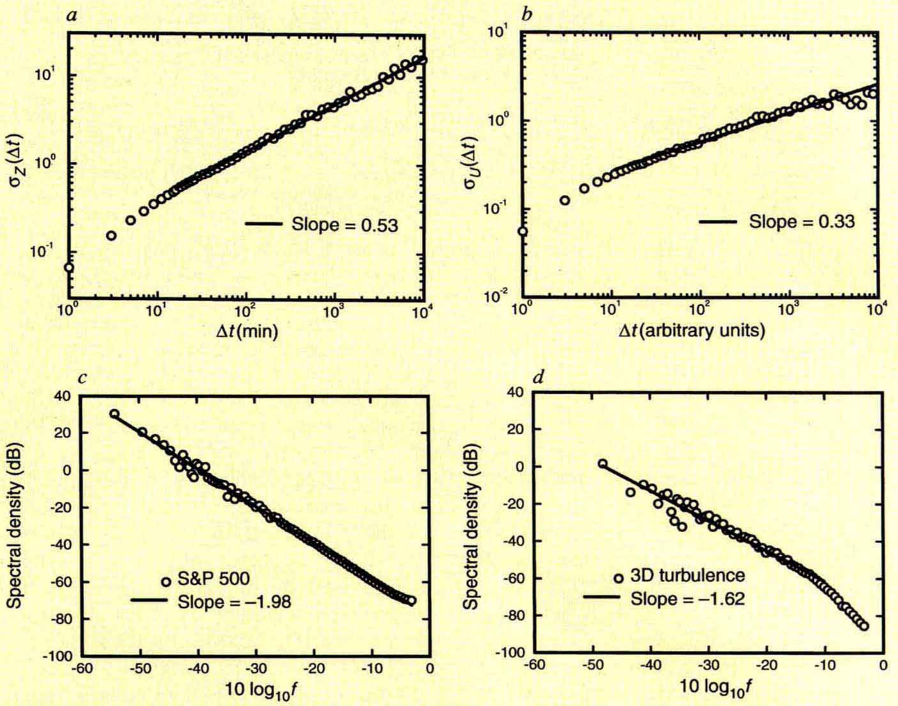


FIG. 1*a*, Standard deviation $\sigma_Z(\Delta t)$ of the probability distribution $P(Z)$ characterizing the price changes $Z_{\Delta t}(t)$ plotted double logarithmically as a function of $\Delta t$ for the S&P 500 time series. After a time interval of superdiffusive behaviour ($0<\Delta t \leq 15$ minutes), diffusive behaviour close to the one expected for a random process with independent identically distributed increments occurs; the measured diffusion exponent 0.53 is very close to the theoretical (uncorrelated) value $1/2$. *b*, Standard deviation $\sigma_U(\Delta t)$ of the probability distribution $P(U)$ characterizing the velocity changes $U_{\Delta t}(t)$ plotted double logarithmically as a function of $\Delta t$ for the velocity-difference time series in turbulence. Data recorded in the atmosphere at a Taylor microscale Reynolds number $R_\lambda$ of the order of 1,500 (data provided by K. R. Sreenivasan). After a time interval of superdiffusive behaviour ($0<\Delta t \leq 10$), a diffusive behaviour close to the one expected for a fluid in the inertial range is observed (the measured diffusion exponent 0.33 is close to the theoretical (anticorrelated) value $1/3$). *c*, Spectral density of the S&P 500 time series for the time period 1984–87 representative of the 6-year time period 1984–89 (an investigation performed for the time period 1986–89 gives a curve overlapping with the figure shown). The $1/f^2$ power-law behaviour expected for a random process with independent increments is observed over a frequency interval of more than 4 orders of magnitude. *d*, Spectral density of the velocity time series of a three-dimensional fully developed turbulent fluid. The $1/f^{5/3}$ inertial range (low frequency) and the dissipative range (high frequency) are clearly observed.

of a price in foreign exchange markets (A. Arneodo *et al.*, preprint cond-mat/9607120 at http://xxx.lanl.gov.).

Features observed in economic data that are not explained in terms of the TLF model are the time dependence of the scale factor parameter $\gamma$ of the TLF distribution, which shows a fluctuating behaviour with bursts of activity localized in limited intervals of time, and the long-range correlations observed in the time evolution of $\gamma$ and in the variance of price changes (two quantities related to what is called 'volatility' in the economics literature) (ref. 5).

Can we reconcile the known intuitive parallels between finance and turbulence with the fact that quantitatively the two phenomena are quite different? This quantitative difference might disappear for a turbulent system in an abstract space of non-integral dimensionality. Theoretical studies[6,7] show that for $d \approx 2.05$ there exists (under the Taylor hypothesis) an uncorrelated turbulent behaviour characterized by a spectral density $S(f) \propto f^{-2}$, just as for the S&P 500. Further study is required to test if a 2.05-dimensional turbulence could be really consistent with the stochastic properties of market data and with the main assumption of mathematical finance that is that no arbitrage is possible in an efficient market[8].

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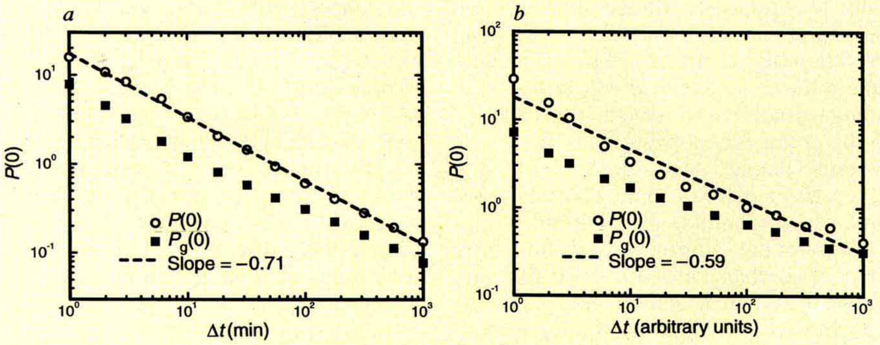


FIG. 2*a*, Probability of return to the origin $P(Z=0)$ for the S&P 500 index (circles) and $P_g(Z=0) = 1/\sqrt{2\pi}\sigma(\Delta t)$ (filled squares) as functions of the time sampling interval $\Delta t$. $P_g(Z=0)$ is the probability of return to the origin expected for a gaussian stochastic process determined by measuring the standard deviation $\sigma(\Delta t)$ of the experimental data. The two measured quantities differ in the full interval implying that the profile of the probability density function (PDF) must be non-gaussian. A power-law behaviour is observed for the entire time interval spanning three orders of magnitude. The slope of the best linear fit is $-0.71 \pm 0.025$. The difference between the two quantities is decreasing when $\Delta t$ increases, implying a convergence to a gaussian process for high values of $\Delta t$. *b*, Probability of return to the origin $P(0)$ (circles) and $P_g(0)$ (filled squares) (defined in *a*) as functions of the time-sampling interval $\Delta t$ for the velocity of the fully turbulent fluid. Again, the two measured quantities differ in the full interval, implying that the profile of the PDF must be non-gaussian. However, in this case, a single scaling power-law behaviour does not exist for the entire time interval spanning three orders of magnitude. The slope of the best linear fit (which is of quite poor quality) is $-0.59 \pm 0.11$.

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