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Why Stock Markets Crash?

PREDICTIONS: The future of the USA stock market
The future of the UK and US real estate market
A complex system view of why stock markets crash NEW
Scientific Prediction of Catastrophes: A New Approach

INTERVIEWS: Interview with Physics World, July Issue (2003), pp. 8-9. NEW phy
Phone interview with FS Newshour, California - Feb. 2003 (MP3)
(Transcription of the Interview)
Phone interview with 21st century Alert Morning Briefing
Press release by UCLA Office of Media Relations

Prediction: The future of the USA stock market

These analyses are researched by D. Sornette and W.-X. Zhou.

Prediction Date: **September 17, 200**

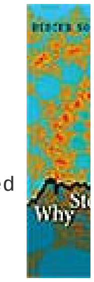
Other Predictions: August 16, 2003

Based on a theory of cooperative herding and imitation working both in bullish as well as in regimes that we have developed in a series of papers, we have detected the existence of a c signature of herding in the decay of the US S&P500 index since August 2000 with high statis significance, in the form of strong log-periodic components.

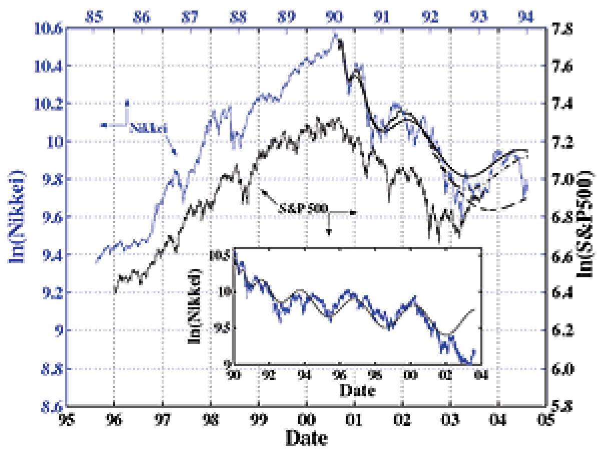
Please refer to the following paper for a detailed description: D. Sornette and W.-X. Zhou, T 2000-2002 Market Descent: How Much Longer and Deeper? Quantitative Finance 2 (6), 468

(2002) (e-print at http://arXiv.org/abs/cond-mat/0209065).

Why Stock Markets Crash: For a general presentation of the underlying concepts, theory, empirical tests and concrete applications, with a discussion of previous predictions, see the recent book Why Stock Market Crash?. Why Stock Market Crash?.



NEW: Testing the Stability of the 2000-2003 US Stock Market Antibubble.
Since August 2000, the USA as well as most other western markets have depreciated almost in synchrony according to complex patterns of drops and local rebounds. We have proposed to describe this phenomenon using the concept of a log-periodic power law (LPPL) antibubble, characterizing behavioral herding between investors leading to a competition between positive and negative feedbacks in the pricing process. Here, we test the possible existence of a regime switching in the US S&P 500 antibu First, we find some evidence that the antibubble might be on its way to cross-over to a shift periodicity described by a so-called second-order log-periodicity previously documented for t Japanese Nikkei index in the 1990s (see last figure of this webpage). Second, we develop a tests to detect a possible end of the antibubble which suggest that the antibubble is still aliv still continue well in the future. Our tests provide quantitative measures to diagnose the end antibubble, when it will come. Such diagnostic is not instantaneous and requires probably th months within the new regime before assessing its existence with confidence. In conclusion, prediction that the S&P 500 is going to plunge progressively from the summer 2003 to botto seems to remain basically intact, possibly with a few month delay extending almost to the en if the shift to the second-order log-periodicity is confirmed.



(click on the figure to enlarge)

This figure shows 9 years of the evolution of the Japanese Nikkei index and more than 7 yea USA S&P500 index, compared to each other. In previous updates, we applied a simple transl years between the two indices, paralleling many analysts' procedures. To compare with our procedure discussed below, this translation can be written mathematically as

(1) time(S&P500) = 1*time(Nikkei) + 11

where the 1 in front of time(Nikkei) means that there is neither a contraction nor a dilation with respect to the other. It is however frustrating to perform such a match by eye-balling a rigorous approach is called for, called a cross-correlation described in the next figure captio cross-correlation analysis shows that the best match between the Nikkei and S&P500 indices obtained by the following mapping between the two times:

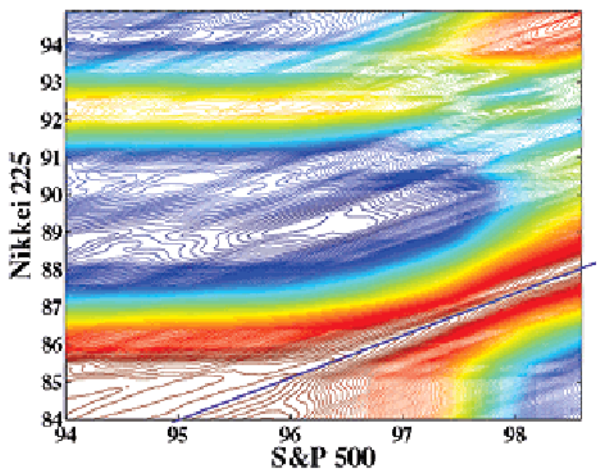
(2) time(S&P500) = 0.9375*time(Nikkei) + 16.25.

Notice that the `1' has been replaced by the factor 0.9375, which means that the intrinsic ti evolution of the S&P500 is flowing faster than its Nikkei counterpart. As references, this exp matches the time pairs (1984 for Nikkei and 1995 for S&P500) corresponding to a local trans 11 years and (1988 for Nikkei and 1998.75 for S&P500) corresponding to a local translation years. The shrinking value of the shift expresses the contraction of the US time versus the Ja time.

When time(Nikkei) = 1990 (that is, Jan-1-1990) which is the very top of the Nikkei bubble, v
time(S&P500) = 2000.6250 (that is, Aug-15-2000) which is the exact onset of the US antibu
in our papers.

Thus, in this figure , the times of the S&P500 and of the Nikkei here are no more mapped to
through the 11-year translation as done in previous updates but have in addition a contracti
by the factor 0.9375 in equation (2). The years are written on the horizontal axis (and mark
tick on the axis) where January 1 of that year occurs.

This figure illustrates an analogy noted by several observers that our work has made quantit
oscillations with decreasing frequency which decorate an overall decrease of the stock marke
observed only in very special stock markets regimes, that we have termed log-periodic "anti
(The term antibubble was inspired by the concept of "antiparticle" in physics. Just as an anti
identical to its sister particle except that it carries exactly opposite charges and destroys its s
particle upon encounters, an antibubble is both the same and the opposite of a bubble; it's t
because similar herding patterns occur, but with a bearish vs. bullish slant). By analyzing the
mathematical structure of these oscillations, we quantify them into one (or several) mathem
formula(s) that can then be extrapolated to provide the prediction shown in the following fig



(click on the figure to enlarge)

This color plot shows the value of the cross-correlation C(t1, t2) between the S&P500 in the
interval [t1, t1+5 years] and the Nikkei in the time interval [t2, t2+5 years], where t1 and t
varied over large time intervals shown in the figure. t1 is the abscissa and t2 is the ordinate
colored contours plot the value of the cross-correlation coefficient C(t1, t2) as a function of t
Regions in red mean large cross-correlations and thus good matching between the two indic
respective intervals. We can observe a line of crests outlined by the violet straight line which
statistically through C(t1, t2) the remarkable matching between the two indices. The violet l
best linear fit to this line of crests and corresponds mathematically to equation (2). This figu
confirms the visual matching by a simple and robust statistical analysis and uncovers the no
of a significant time contraction of the patterns of the S&P500 compared with those of the N
explained above. The implication is clear: it is naive to expect a perfect superposition describ
simple translation.

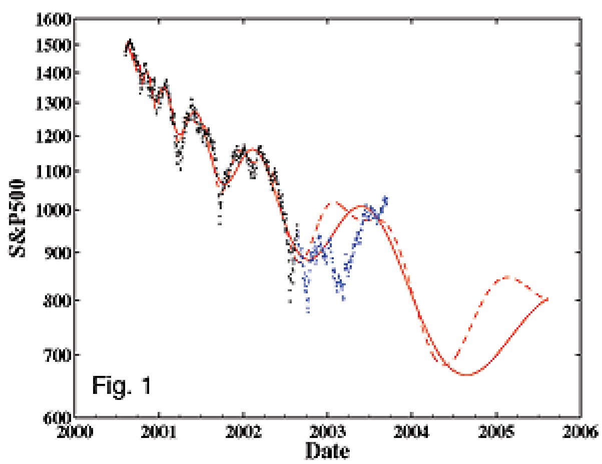
Discussion of the Nikkei-S&P500 matching patterns: The matching between the Nikkei and t
time series obtained here by a rigorous quantitative analysis of the cross-correlation of the t
time series should not lead to the belief that the S&P500 index is bound to follow blindly this
correlation in the future. In contrast with chartism or technical analysis, we try to develop a
understanding of these bubble-antibubble phases. The similitude between the Nikkei and US
are part of the search for "universal" properties, that allow us to establish a theory (in short,
is a story of repeatable/reproducible occurrences). Using this theory then allows us to descri
idiosyncratic behaviors, that is, deviations from one case to another, or in other words, the p
evolutions that are not universal. This is what should give us an hedge for predictions.

Already, as early as September 2002, in our paper [*] based on an analysis carried on the s
market time series available up to Aug. 25, 2002, we wrote that we could see a clear differe
between the Nikkei and the SP500. Thus the qualitative analogy is there but, quantitatively,

serious differences. Technically, after two years and a half after the top in Dec. 31, 1989, we the Nikkei has started to shift to another antibubble regime while no such shift is yet detecta more than three years since the start of the antibubble in the US. In addition, the US marke been characterized by much stronger crashes and rallies, modelled below by our "zero-phase Weierstrass" functions. These two facts suggest to us that the herding forces are even stron US and that investors react even more on hair-trigger to any "news".

To sum up, the similarities between the shifted Nikkei and the S&P500 are qualitative: bubbl preceding antibubble, strong speculation and herding, similar fear and herding in the anti-bu regime, some problems with bad loans or bad accounting, strong commitment from the cent and governments to provide liquidity and cash... But there are differences and these differer detected. Thus, we are not proponents of a superposition of the two time series to predict th evolution of the US stock markets. It is clear to us that their future will be different, accordir forecasts proposed below.

[*] D. Sornette and W.-X. Zhou, The US 2000-2002 Market Descent: How Much Longer and Quantitative Finance 2 (6), 468-481 (2002)
http://www.iop.org/EJ/S/1/NCA203394/RCM0rqd2bn5eBW0XZGGwvA/toc/1469-7688/2/6
(http://arXiv.org/abs/cond-mat/0209065)



(click on the figure to enlarge)

Fig. 1 shows the predictions of the future of the US S&P 500 index performed on Aug. 24, 20 continuous line is the fit and its extrapolation, using our theory capturing investor herding ar behavior. The theory takes into account the competition between positive feedback (self-fulf sentiment), negative feedbacks (contrariant behavior and fundamental/value analysis) and i (everything takes time to adjust). Technically, we use what we call a "super-exponential pov log-periodic function" derived from a first order Landau expansion of the logarithm of the pri dashed line is the fit and its extrapolation by including in the function a second log-periodic l The two fits are performed using the index data from Aug. 9, 2000 to Aug. 24 2002 that are black dots. The blue dots show the daily price evolution from Aug. 25, 2002 to Sep. 17, 200: large (respectively small) ticks in the abscissa correspond to January 1st (respectively to the of each quarter) of each year.

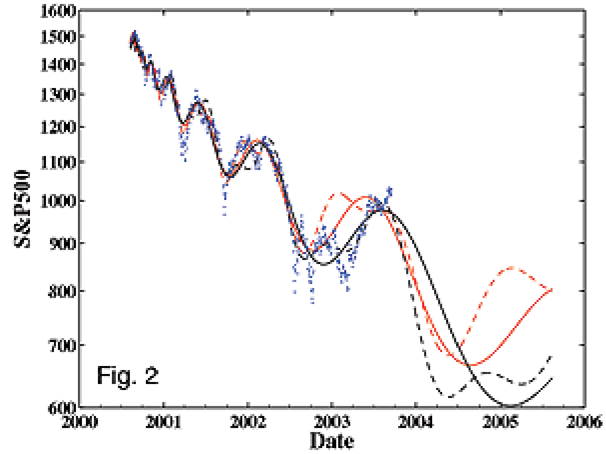


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Fig. 2 shows the new predictions of the future of the US S&P 500 index using all the data fro
2000 to Sep. 17, 2003, illustrated by (continuous and dashed) black lines. Again, the continu
the fit and its extrapolation using the super-exponential power-law log-periodic function deri
the first order Landau expansion of the logarithm of the price, while the dashed line is the fit
extrapolation by including in the function a second log-periodic harmonic. We also present th
previous fits (red lines) performed on Aug. 24, 2002 (shown in Fig. 1) for comparison, so as
an estimation of the sensitivity of the prediction and of its robustness as the price evolves. T
dots show the daily price evolution from Aug. 9, 2000 to Sep. 17, 2003. The large (respectiv
ticks in the abscissa correspond to January 1st (respectively to the first day of each quarter)
year.

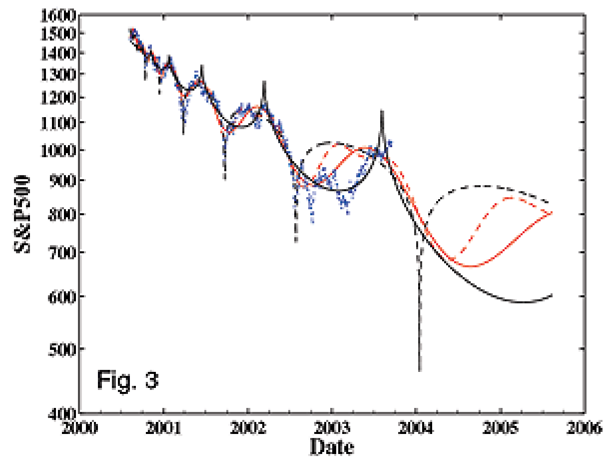

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Fig. 3 shows the predictions of the future of the US S&P 500 index obtained by applying the
'zero-phase' Weierstrass-type function, which is another child of our general theory of imitat
herding between investors. As for the previous figures, our theory takes into account the co
between positive feedback (self-fulfilling sentiment), negative feedbacks (contrariant behavi
fundamental/value analysis) and inertia (everything takes time to adjust). This 'zero-phase'
Weierstrass-type function adds one additional ingredient: it attempts to capture the existenc
'critical' points within the anti-bubble, corresponding to accelerating waves of imitation withi
scale unraveling of the herding anti-bubble. The continuous black line is the forward predicti
the data from Aug. 9, 2000 to Sep. 17, 2003, while the dashed black line is the retroactive p
using the data from Aug. 9, 2000 to Aug. 24, 2002. Both lines are reconstructed and extrapo
the fits to a six-term zero-phase Weierstrass-type function. We also present the two previou
lines) performed on Aug. 24, 2002 (shown in Fig. 1) for comparison. The blue dots show the
evolution from Aug. 9, 2000 to Sep. 17, 2003. The large (respectively small) ticks in the abs
correspond to January 1st (respectively to the first day of each quarter) of each year.

The striking development observed in the update on June, 19, 2003 is again confirmed. The

phase' Weierstrass-type function, which up to May 18, 2003 selected a series of downward c
crashes, is now selecting as the dominant critical points the bullish accelerations. The formul
deciphering the coexistence of two sets of critical points: (i) the crashes previously recogniz
have punctuated the descent in the last three years and (ii) the bursts of upward acceleratin
This formula is however not rich enough in its present version to capture these two sets sim
and has to choose between the two, as a result of their relative strengths. This new twist do
change fundamentally our prediction of a drastic turn towards a systematic downward trajec
summer of 2004.

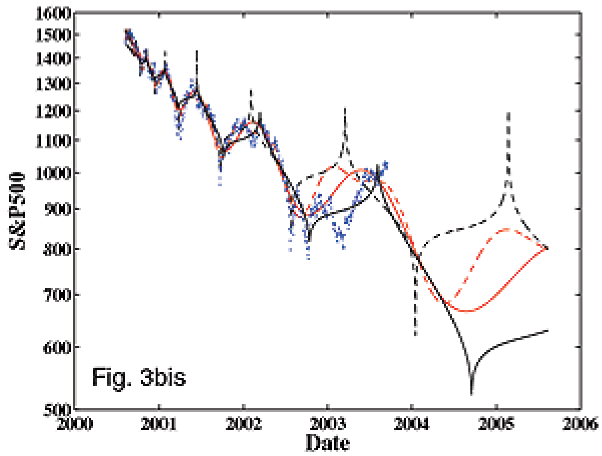

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Fig. 3bis is a modification of the 'zero-phase' Weierstrass-type function shown in Fig. 3, whic
only odd-terms in the expansion (this will be elaborated upon in a future technical communi
this trick, the odd-zero-phase Weierstrass-type function is able to describe simultaneously th
of critical points mentioned in the caption of Fig. 3. The continuous black line is the forward
using all the data from Aug. 9, 2000 to Sep. 17, 2003, while the dashed black line is the retr
prediction using the data from Aug. 9, 2000 to Aug. 24, 2002. Both lines are reconstructed a
extrapolated from the fits to a six-term odd-zero-phase Weierstrass-type function. We also p
two previous fits (red lines) performed on Aug. 24, 2002 (shown in Fig. 1) for comparison. T
dots show the daily price evolution from Aug. 9, 2000 to Sep. 17, 2003. The large (respectiv
ticks in the abscissa correspond to January 1st (respectively to the first day of each quarter)
year.

In conclusion, the coexistence of the strong downward crashes and upward rallies in the ove
bubble regime suggests to us that the market is completely dominated by sentiment, confid
lack thereof and by herding. These mechanisms are amplifying any news, perturbation or ru
spreading in the network of investors.

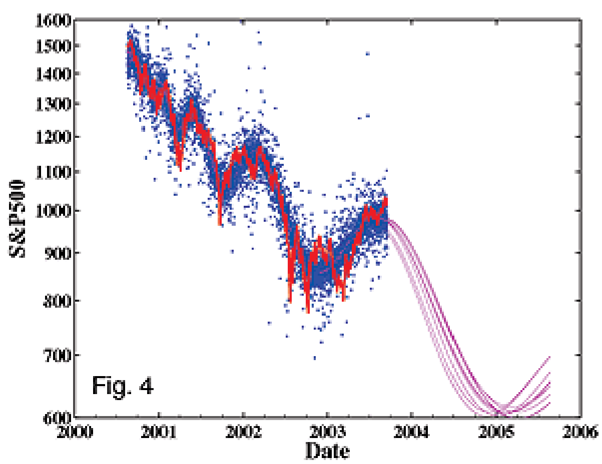

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Fig. 4 extends Figs. 1 and 2 by performing a sensitivity analysis on the simple log-periodic f (continuous lines in Figs. 1 and 2), in order to assess the reliability and range of uncertainty prediction. Using the fit shown in black solid lines in Fig. 2, we have generated 10 realizatior artificial S&P 500 by adding GARCH noise to the black solid line. GARCH means "generalized regressive conditional heteroskedasticity". It is a process often taken as a benchmark in the industry and describes the fact that volatility is persistent. The innovations of the used GARC have been drawn from a Student distribution with 3 degrees of freedom with a variance equa of the residuals of the fit of the real data to ensure the agreement between the statistical pr these synthetic time series and the known properties of the empirical distribution of returns. are shown as the bundle of 10 curves in magenta. This bundle of predictions is coherent and a good robustness of the prediction. The typical width of the blue dots give a sense of the va that can be expected around this most probable scenario. The real S&P 500 price trajectory as the red wiggly line.

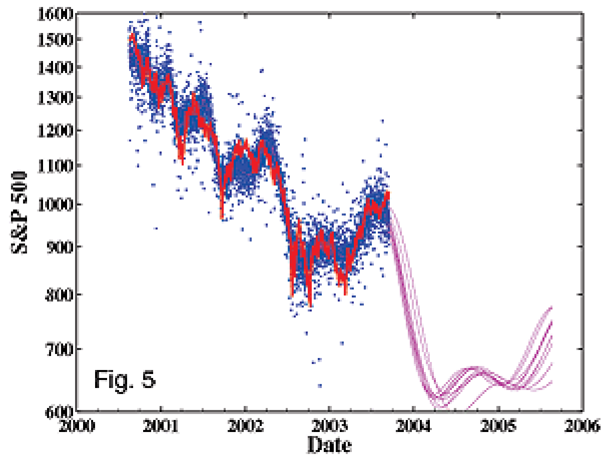

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Fig. 5 extends Figs. 1 and 2 by performing a sensitivity analysis on the log-periodic formula second log-periodic harmonic (dashed lines in Figs. 1 and 2), in order to assess the reliabilit range of uncertainty of the prediction. Using the fit shown in dashed solid lines in Fig. 2, we generated 10 realizations of an artificial S&P 500 by adding the GARCH noise (described in th caption of Fig. 4) to the dashed solid line. We have then fitted each of these 10 synthetic noi of the S&P 500 by our log-periodic formula. This yields the 10 curves shown here in magenta shows that the log-periodic formula with a second log-periodic harmonic (dashed lines in fig 2) is also providing stable scenarios: the precise timing of the highs and lows remain robust respect to the realization of the noise. The real S&P 500 price trajectory is shown as the red line.

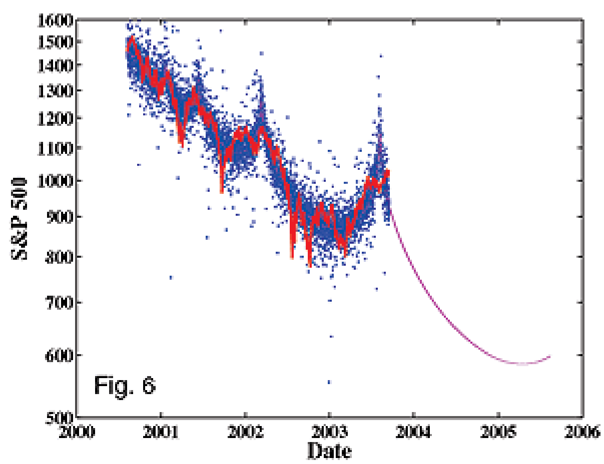

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Fig. 6 extends Fig. 3 by performing a sensitivity analysis on the 'zero-phase' Weierstrass-typ in order to assess the reliability and range of uncertainty of the prediction. Using the fit shov solid lines in Fig. 3, we have generated 10 realizations of an artificial S&P 500 by adding A G noise to the black solid line. The innovations of the used GARCH noise have been drawn from distribution with 3 degrees of freedom with a variance equal to that of the residuals of the fit real data by the black continuous curve. We have then fitted each of these 10 synthetic nois the S&P 500 (shown as the blue dots) by our 'zero-phase' Weierstrass-type function. This yi narrow bundle of 10 curves shown here in magenta. This bundle of predictions is very coher suggests a good robustness of the prediction. The typical width of the blue dots give a sense variability that can be expected around this most probable scenario. The real S&P 500 price is shown as the red wiggly line.

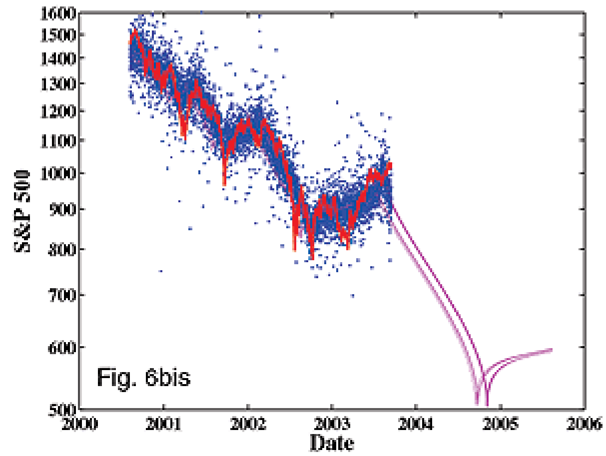

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Fig. 6bis is the same as Fig. 6 but for the odd-zero-phase Weierstrass function shown in Fig.

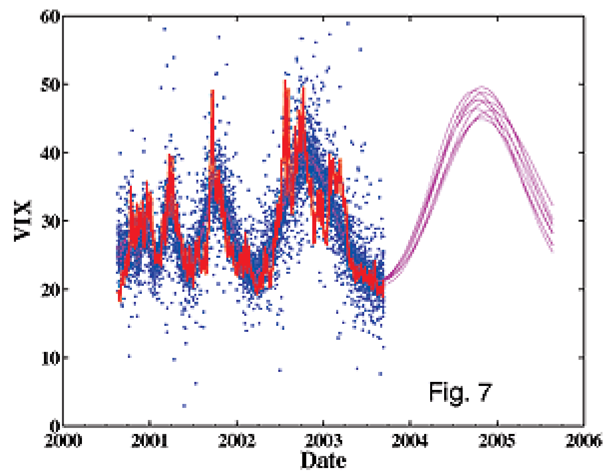

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Fig. 7 analyses the VIX index by fitting it with our simple log-periodic formula. The VIX index the world's most popular measures of investors' expectations about future stock market vola is, risk). See http://www.cboe.com/micro/vixvxn/introduction.asp. For historical data, see http://www.cboe.com/micro/vixvxn/specifications.asp. The VIX time series is shown as the r curve. We have followed the same procedure as for Figs. 4-6: (i) we fit the real VIX data wit simple log-periodic formula; (ii) we then generate 10 synthetic time series by adding GARCH the fit; (iii) we redo a fit of each of the 10 synthetic time series by the simple log-periodic fo thus obtain the bundle of 10 predictions shown as the magenta lines. Strikingly, we first obs our log-periodic formula is able to account quite well for the behavior of the VIX index, stren the evidence that the market is presently in a strong herding (anti-bubble) phase. Note also good stability of the predictions, suggesting a reasonable reliability.

DETECTION OF A CHANGE OF REGIME: POSSIBLE POSTPONING OF THE ``CRASH''

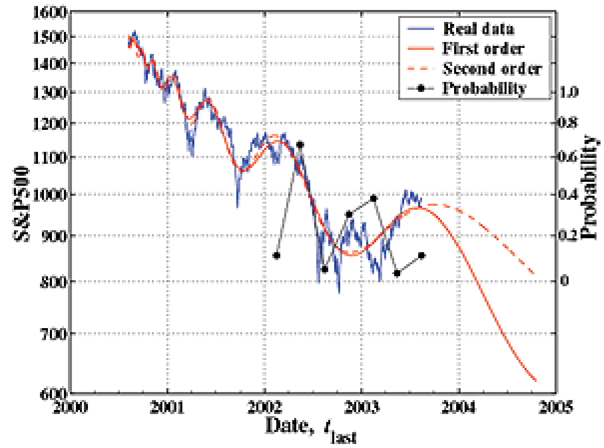

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Fig. 8 compares the fit with the simple log-periodic formula shown as the continuous red line the same as the continuous black line in Fig.2) with the fit using the log-periodic formula de a second-order Landau expansion shown as the red dashed line. In our paper appeared in th December issue of Quantitative Finance in 2002, we stated that the simple log-periodic form enough to fit the S&P 500 antibubble and we thus concluded that the S&P 500 index had not entered into the second phase in which the angular log-frequency may start its shift to anoth as did the 1990 Nikkei antibubble after about 2.5 years. This figure shows that, 10 months l are now starting to detect the occurrence of such a change of regime. The statistical tests de below give the probability (shown as the full black dots and the right vertical scale) to reject hypothesis that the market has entered the second phase in which the angular log-frequency to another value. These results here open very seriously the possibility that, indeed, we have cross-over regime in log-frequency shift. The improved second-order log-periodic formula sh red dashed line suggests that there will be a delay in the expected drop, which rather than c now, may wait until November-December 2003. Future updates will test thoroughly how this is unfolding.

CALCULATION OF THE PROBABILITY FOR THE SECOND SCENARIO OF A DELAY OF T CRASH:

We have fitted the S&P 500 antibubble data of three years from 2000/08/09 to 2003/08/15 first-order and second-order Landau expansions, as shown in Fig. 8. We obtain a log-likeliho T=51 for the two fits. Due to the finite size of the data set and the non-Gaussianity and stro correlation of the fit residuals, Wilks' theory does not apply. To assess the statistical significa second-order formula, we have developed the following bootstrap test capturing the noise st to the monthly interval: (1) Decompose the residues in one-month intervals; (2) Reshuffle t month intervals of the residuals at random. Since there are about three years of data = 36 r there are 36! (factorial 36) ways of reshuffling the monthly residues; (3) Add the reshuffled the first-order formula obtained by the first fit to the first-order formulae; (4) Redo a fit with order and with the second-order formula. Calculate the corresponding log-likelihood ratio T f two fits for the given reconstruction; (5) Do steps 2-4 one thousand times and count how m the value T=51 is exceeded. The choice to reshuffle entire monthly sequences of residues is keep the dependence patterns up to the monthly scale, so as to test how dependence struct one month may interfere with the detection of log-periodicity and of its frequency shift. The scale is a compromise between having many statistical realizations (favoring smaller time in and keeping as much as possible all the idiosyncratic textures of the price times series that c the large scale log-periodicity. We perform 1000 simulations. The average log-likelihood rati +\- 25.8. The empirical probability that T>51 is 11.1%. We conclude that the null hypothesi 500 has not experienced a phase crossover cannot be rejected at the significance level of 90 However, the null hypothesis can be rejected at a significance level of 88%. This result is co with the significant discrepancy between the two extrapolations in the future till the end of y as shown in Fig. 8. In sum, we conclude that the phase shift from the first order to the secon has started but is not yet mature. A paper containing detailled and thorough analyses of this over is in preparation

ANNOUNCEMENT CONCERNING THE POSSIBLE DEATH OF THE ANTIBUBBLE:

As this is obviously of strong interest from a theoretical and practical point of view developed a technique to forecast the end of the anti-bubble. The results have bee and the paper is almost ready for release. Our main conclusion is that we are still i speculative antibubble and have been able to reject strongly the hypothesis that th

antibubble has died.

Cautionary note:
Note that extrapolating is often a risky endeavor and needs to be justified. In our c extrapolations, which give the forecasts, are based on the belief that the theory an equations used above embody the major forces in the market at the macroscopic s leads to the possibility of describing several probable scenarios. We do not believe existence of deterministic trajectories but we aim at targeting the most probable fu paths.

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