Tools for Options Trading in a Crazy World

MathFin Conference, March 16, 2021

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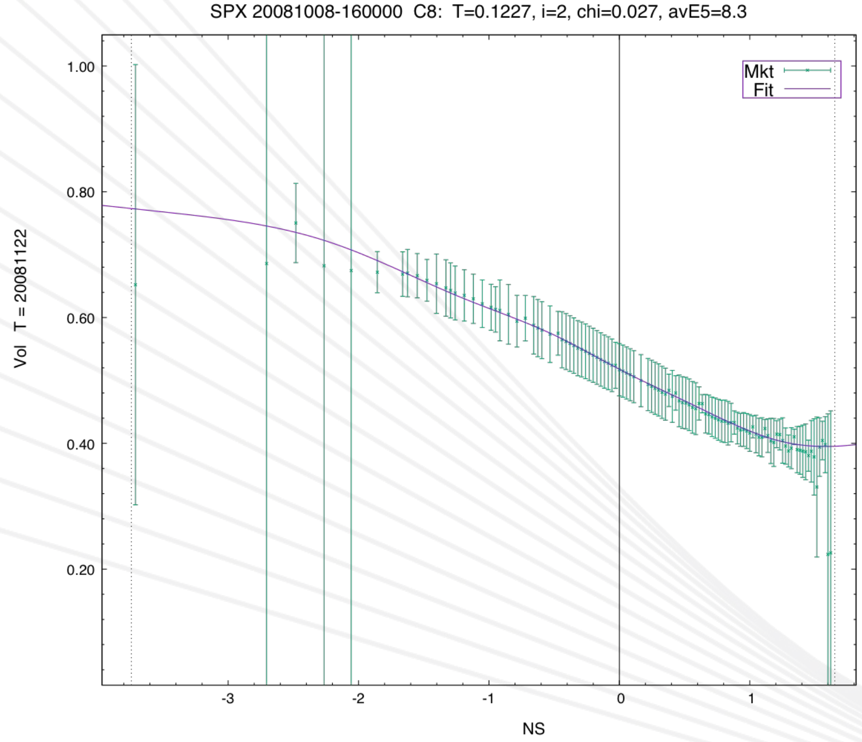
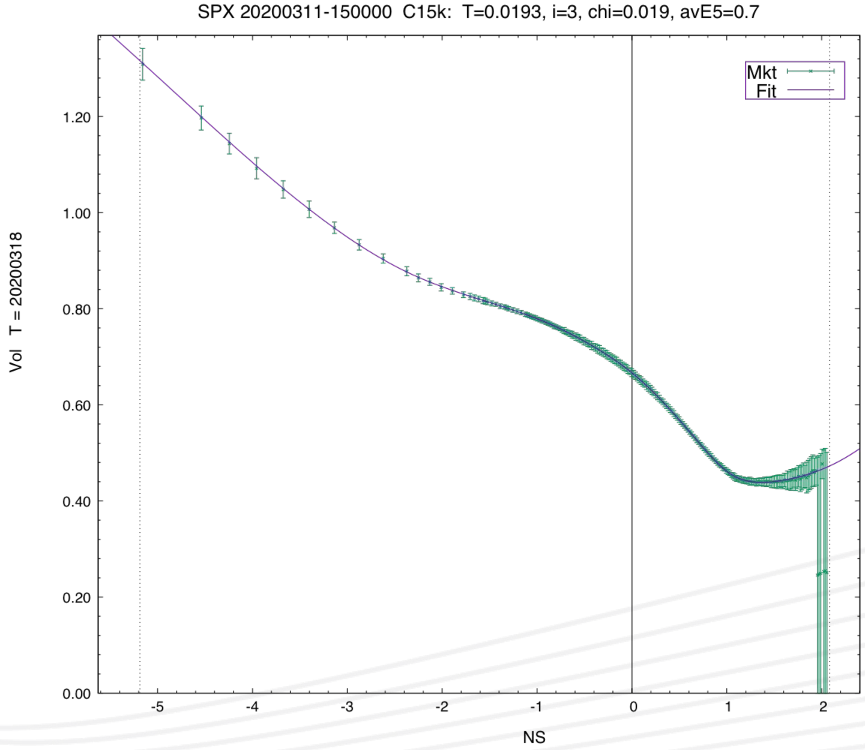
Vol Skews: 2008 versus 2020





Parameter TS: 2008 versus 2020

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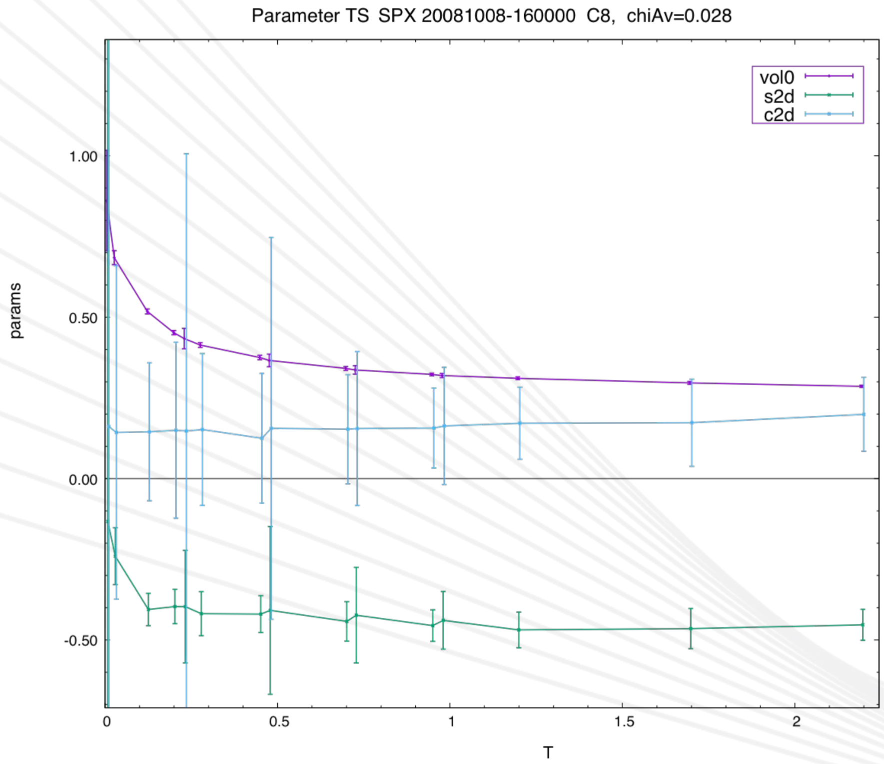

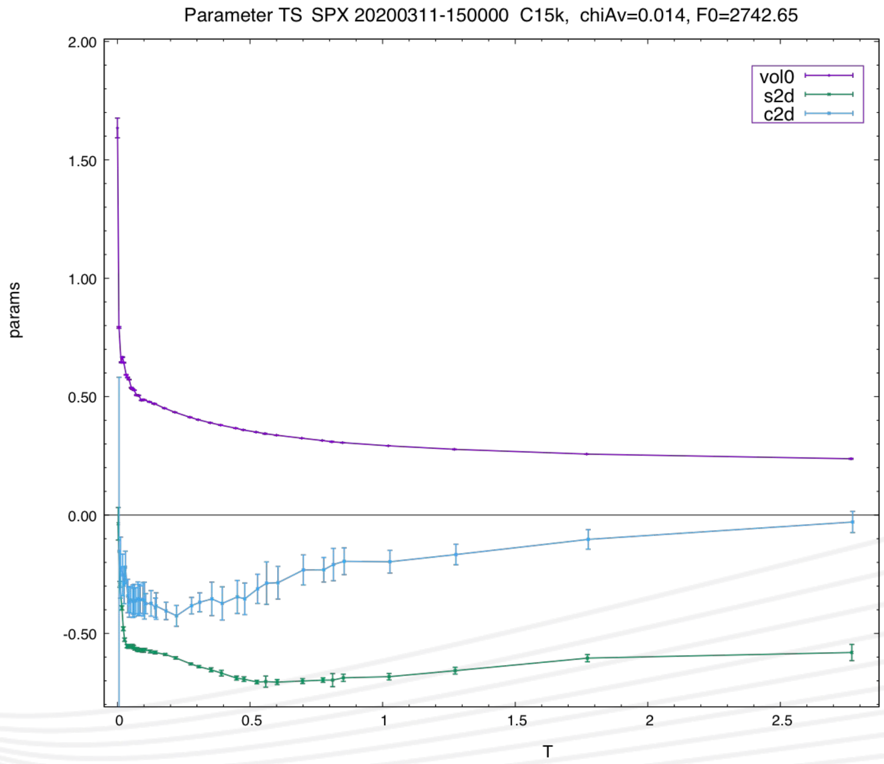

Introduction and Summary

- Derivatives Trading has become (been forced to?) more transparent since 2008.
- The listed options market has grown dramatically over the last 20 years, incl. last!
- OTC flow and exotics markets can't ignore the listed (vanilla) market.
- Vanilla vol surfaces are the foundation of any derivatives business.
- Despite the liquidity and sophistication of the listed market it is not trivial to know at all times what vanillas are worth, or their greeks.
- It is a well-known "holy-grail" problem to produce sensible (arbitrage- and bias-free) theos/vol surfaces from the listed options market, especially in real-time (in any time, often…).
- We discuss the current state of the listed options market and illustrate why there are a lot of non-trivial data, modeling and algorithmic problems to solve.
- We will take an options/derivatives quant perspective.

Equity Options Markets Overview

- In US alone: circa 1,400,000 options on 4,600 underliers (just OPRA)
  - SPX has about 18,000 options (calls and puts) and about 40 expiries these days!
- Vanilla valuation is complicated due to dividends, borrow costs, events, and vol curves with lots of structure. Robustness is crucial, esp. in an HFT world.
- OMM: All options can only be valued with real-time, robust implied borrow curves and well-designed & calibrated volatility surfaces.
  - Also required for real-time risk, PnL decomposition/explain, margin, exotics, etc.
- All borrow and vol curve modeling and fitting analytics are proprietary.
  - In-house dev is a huge (ongoing) opportunity cost and business risk.
  - Now one vendor's library, Vola Dynamics, can help!

Implied Vols and Surfaces

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- Implied volatility surfaces (and borrow cost curves) are the standard approach to summarizing the vanilla options market in an intuitive and compact manner.
- They provide the fundamental building block for the trading of vanillas (listed and OTC), as well as flow derivatives and exotics.
- There are many quant problems facing options and derivatives trading desks, but the long-standing problem of constructing sensible, arbitrage-free volatility surfaces from options market prices is perhaps the single hardest problem.

Implied Vols and Surfaces (cont'd)

- Before an implied vol can be calculated, other problems have to be solved:
  - Choice of "micro price" -- something better than inside bid and ask.
  - Handling of zero-bids.
  - Choice of "vol time" (aka "VTTX"), perhaps including "event time".
  - Dividend Modeling (no consensus even for Vanilla options!)
  - "De-Americanization" of American-exercise options (ETFs and stocks).
- See other talks, papers, and info on Vola Dynamics website (or ask...).
- NOTE: The problem in its purest form with less of these complications exists for (European exercise-style) SPX index options.

Vol Surface Parametrizations

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- There are of advantages to having a vol curve parametrization per term with:
    - Intuitive parameters, as independent as possible, stable from fit to fit.
    - Smooth (in strike) over regions that are strongly correlated (cross-hedging…).
    - Little term-structure if possible (except on short end perhaps).
    - Makes it “easy” to avoid arbitrage, e.g. Lee bounds should be built in.
    - No hacks! (in wings, etc).
    - “SVJ” etc vol curves should be fittable within fraction of bp.
- A parametrization of the term-structure is not as crucial (it’s also very hard…): one can T-interpolate and T-extrapolate good parametric curves quite easily.
    - But avoiding calendar arbitrage is crucial -- somehow curves have to be tied together.

Our parametrization approach

- Work one term at a time, impose smoothness across terms.
- Factor out overall vol level (ATF) as: $\sigma_0 := \sigma(T, K = F)$.
- Define "shape" curve $f(z) = f(z|\mathbf{p})$ as function of normalized strike (NS)[1]

$$z := \frac{y}{\hat{\sigma}_0} = \frac{\log(K/F)}{\sigma_0\sqrt{T}}$$

  such that

$$\sigma(z)^2 = \sigma_0^2 \, f(z|\mathbf{p})$$

- There are no standard definitions – we define dimensionless "skew" and "smile/convexity" as slope and curvature of shape curve:

$$f(z) =: 1 + s_2 \, z + \tfrac{1}{2} c_2 \, z^2 + \ldots$$

No-Arbitrage Constraints in Vol-Space

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- **No butterfly arbitrage**: Implied density ρ should be positive:

$$\hat{C}(T,K) \;=\; \int_0^\infty dS_T\,(S_T - K)_+\;\rho_T(S_0 \to S_T)$$

$$\Rightarrow \quad \partial_K^2 \hat{C}(T,K) \;=\; \rho_T(S_0 \to S)|_{S=K}$$

- **No calendar arbitrage**: Total BS variance $w(y) := T\sigma(y)^2$ has to be increasing in T at any fixed y.

- Necessary (but generally not sufficient) constraint on the asymptotic wing behavior of implied vols (R. Lee, 2004):

$$w(y) \leq 2|y| \qquad\qquad \text{as} \quad |y| \to \infty$$

Specific Curves: Parabolas

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- What are simplest possible implied vol curves? Need at least 3 parameters for ATF behavior.
- Vendors often use

$$\sigma(y)^n \;=\; \sigma_0^n \,(1 + s\,y + \tfrac{1}{2} c\,y^2) \qquad \text{(or in terms of } z\text{)}$$

- Obviously has arbitrage in wings for $n = 1, 2$.
- Slight hope for $n = 4$, but would imply symmetric wings, which is intuitively and empirically wrong.
- Positivity has to be enforced too.
- Must do better...

Specific Curves: S3/SSVI

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- Simplest sensible curve with 3 parameters ($c_2 \geq 0$):

$$\sigma^2(z) \;=\; \sigma_0^2 \;\left(\tfrac{1}{2}(1+s_2 z) + \sqrt{\tfrac{1}{4}(1+s_2 z)^2 + \tfrac{1}{2}c_2 z^2}\right)$$

- Was independently discovered by TRK (2003, "S3") and Gatheral/Jacquier (2013, "SSVI" = Simple SVI).
- Allows surprisingly varied skew shapes, including "takeover-for-cash" curves as $c_2 \to 0$.
- Allows fitting of vast majority of US equity names.
- Very easy to avoid arbitrage (especially butterfly).
- In fact, in terms of the dimensionless variables $\hat{\sigma}_0, s_2, c_2$ can completely answer the butterfly-arbitrage question...

See our paper on SSRN for details about S3 curve, including simple necessary and sufficient no-butterfly arbitrage conditions in terms of parameters.

Beyond the Simplest Curves: 5 Parameters (SVI, etc)

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- Besides 3 parameters for ATF would be nice to have independent parameters $C_\pm$ for wings:

$$\sigma(z)^2 \;\to\; \sigma_0^2\; C_\pm\; |z| \qquad \text{as} \quad z \to \pm\infty \qquad (\hat{\sigma}_0 C_\pm \le 2)$$

- For S3/SSVI: $\quad C_\pm \;=\; \sqrt{\tfrac{1}{4}s_2^2 + \tfrac{1}{2}c_2} \;\pm\; \tfrac{1}{2}s_2$
- For Jim Gatheral's SVI and others (JW/L5, TRK) the $C_\pm$ are independent parameters (constrained by $-C_- \le s_2 \le C_+$).
- Just some algebra to re-express their "raw" parametrization in terms of natural parameters $\sigma_0, s_2, c_2, C_-, C_+$. (Or minimum variance ratio instead of c_2.)
- Can fit some names better than with S3/SSVI.... but surprisingly not much better in many cases!?
- Certainly can not fit W-shaped curves around events (still $c_2 \ge 0$).

Beyond S3/SSVI, S5/SVI

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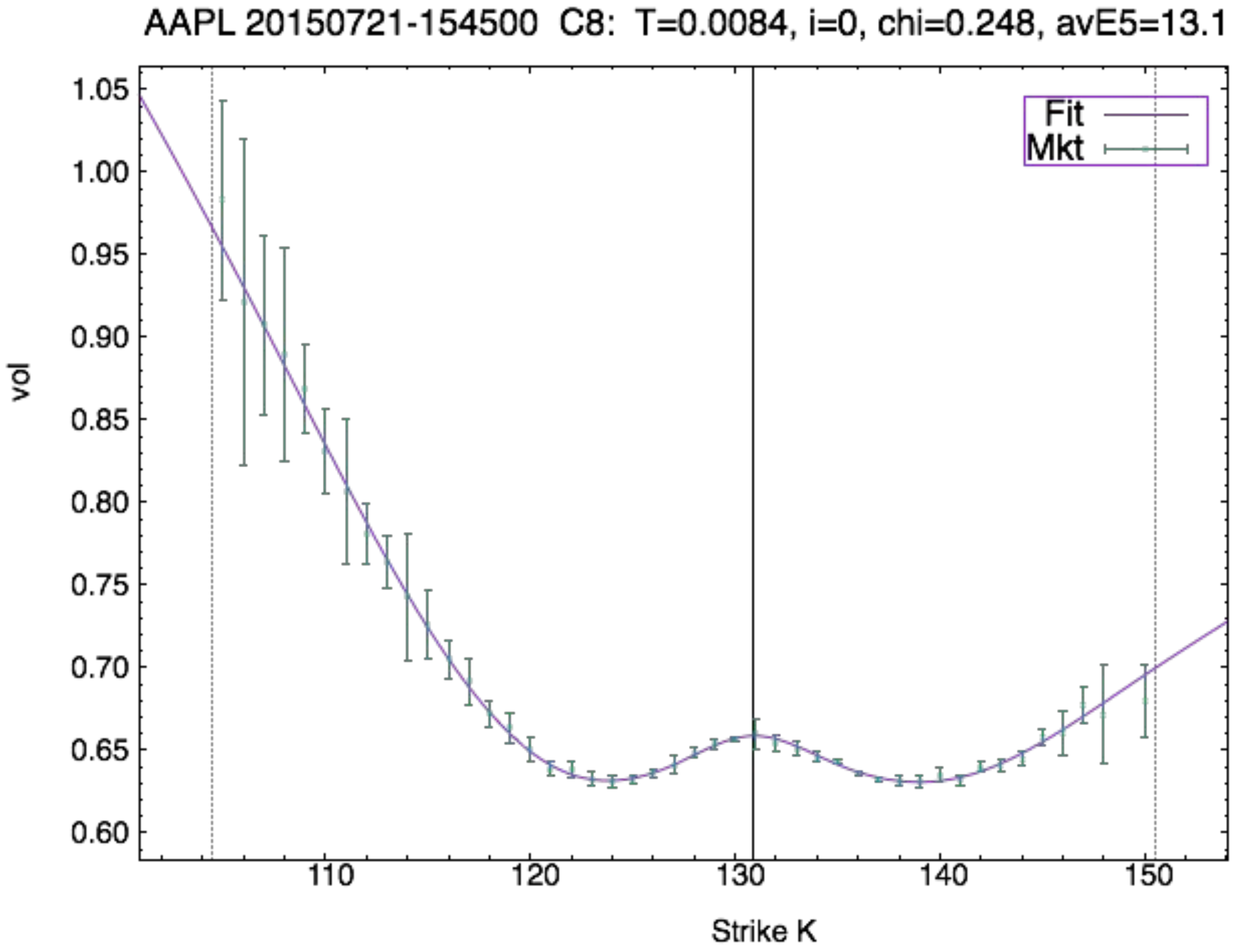
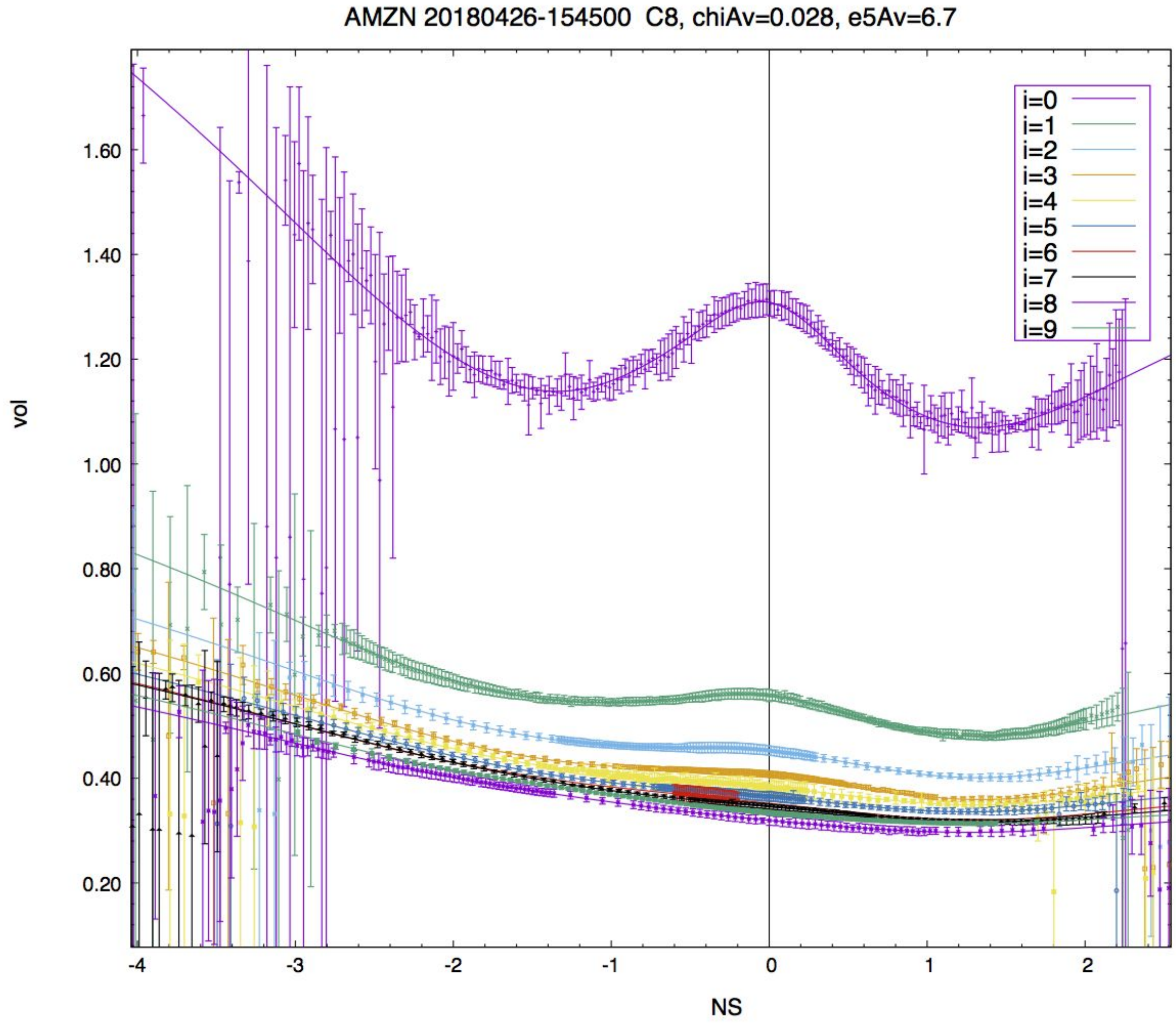
- Liquid names can not be fit with simple curves like S3, S5, SABR (**S* curves**):
  - They have a unique maximum in their curvature around ATF and it is non-negative, which is not what the market always wants for liquid names.
  - Note e.g. that any kind of **event** (earnings, elections, Brexit, etc) leads to **bi- or multi-nodal distributions**, which can not be modeled by S* curves.
  - This is true not just for equity, but **also for FX, IR**.
- Need family of curves that allows more general curvature structures, including $c2 < 0$, but can be made arbitrage-free and fitted robust and fast.
- Vola Dynamics designed such a family of curves: **C* curves**: C6, C7, C8, …., C16
- Let's look at some examples…



AAPL 2015-07-21

C8 fit of W-shaped vol curves around earnings

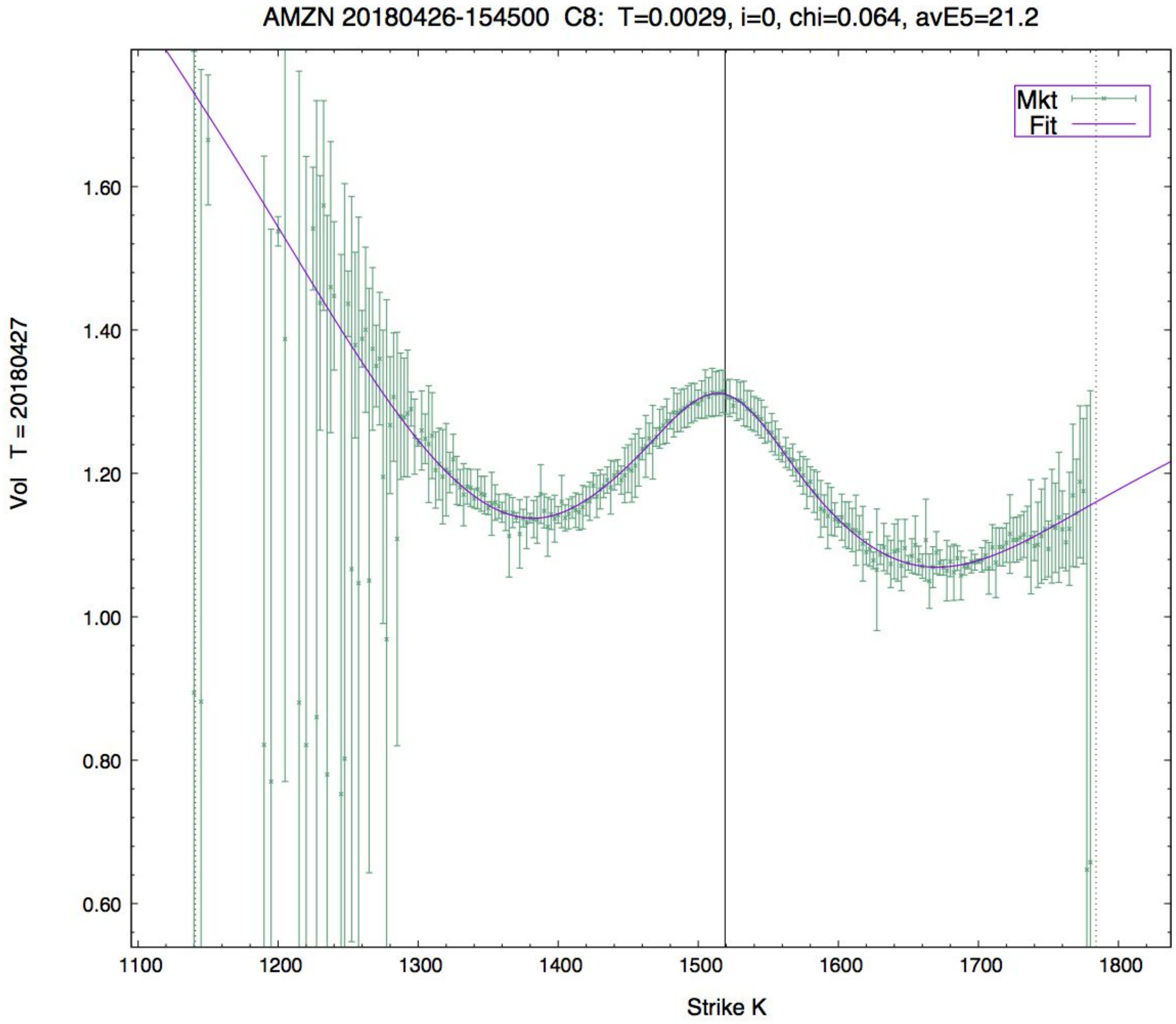
Note "quotes in the middle of spread" in call wing...



AMZN 2018-04-26 earnings day

C8 Vol vs NS

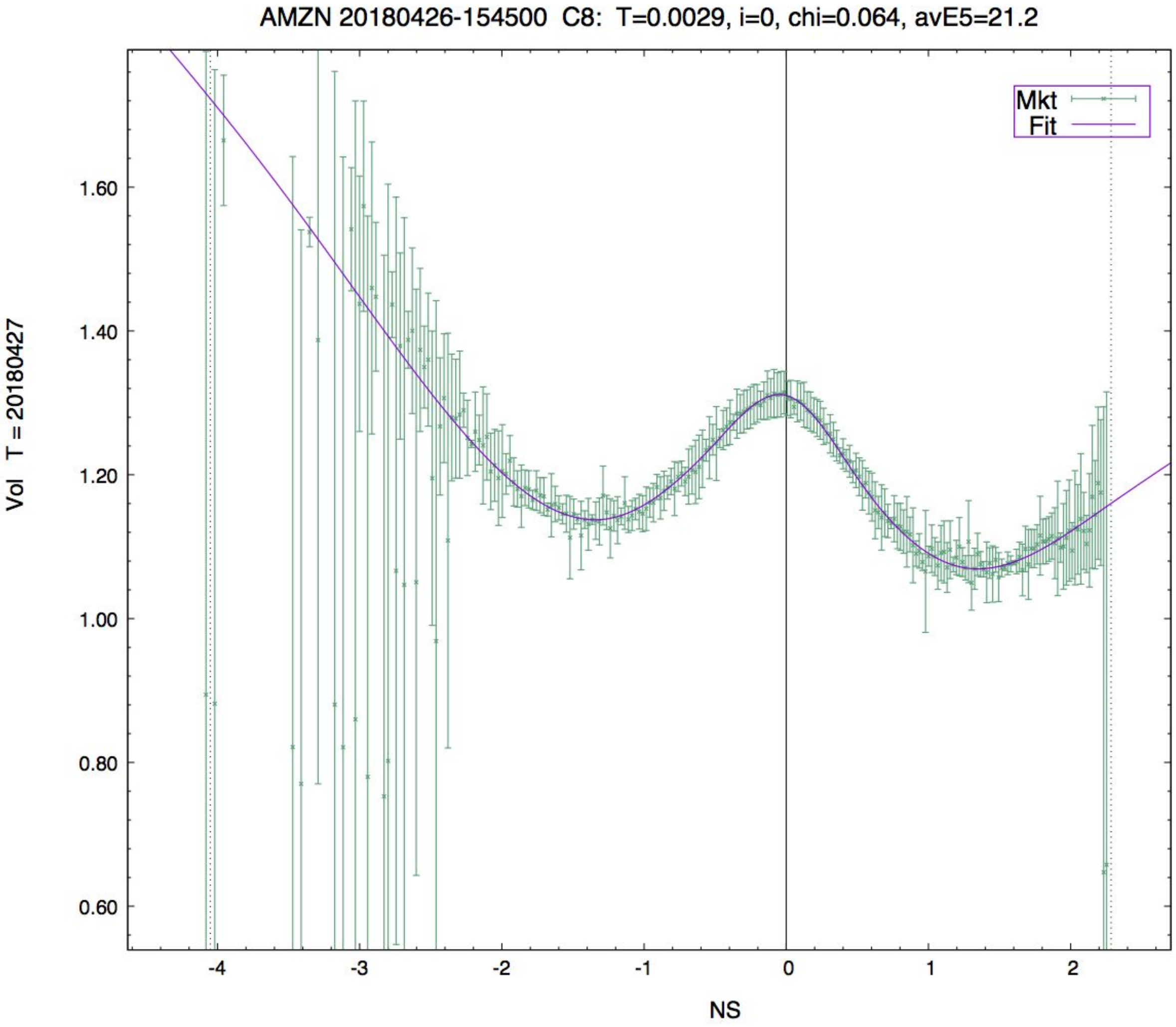
Interesting Thursday: Earnings, new weekly listed, etc.



AMZN 2018-04-26
earnings day

Vol fit for first term, i=0, K-space

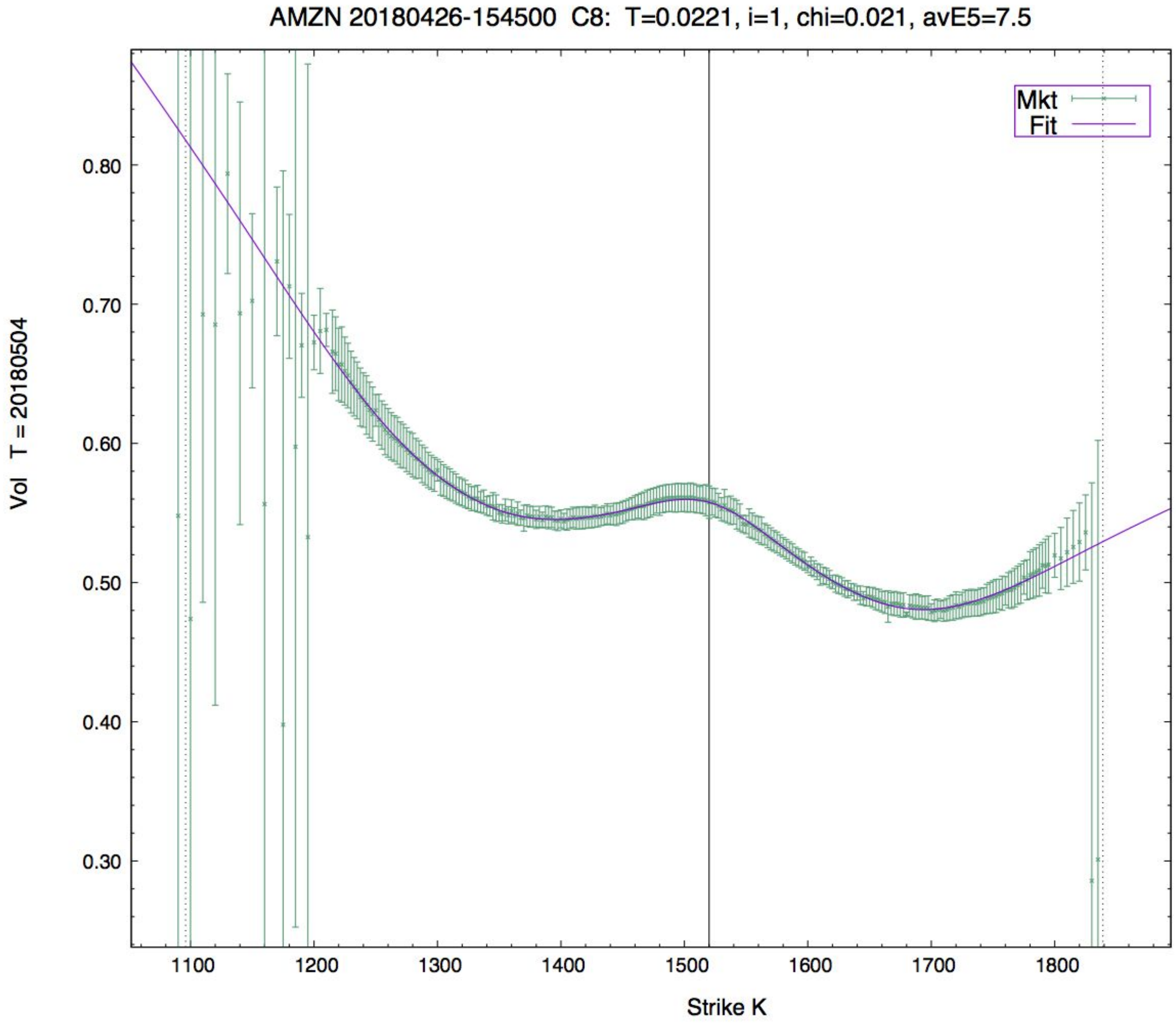
Most negative c2 ever!



AMZN 2018-04-26
earnings day

Vol fit for first term, i=0, NS-space

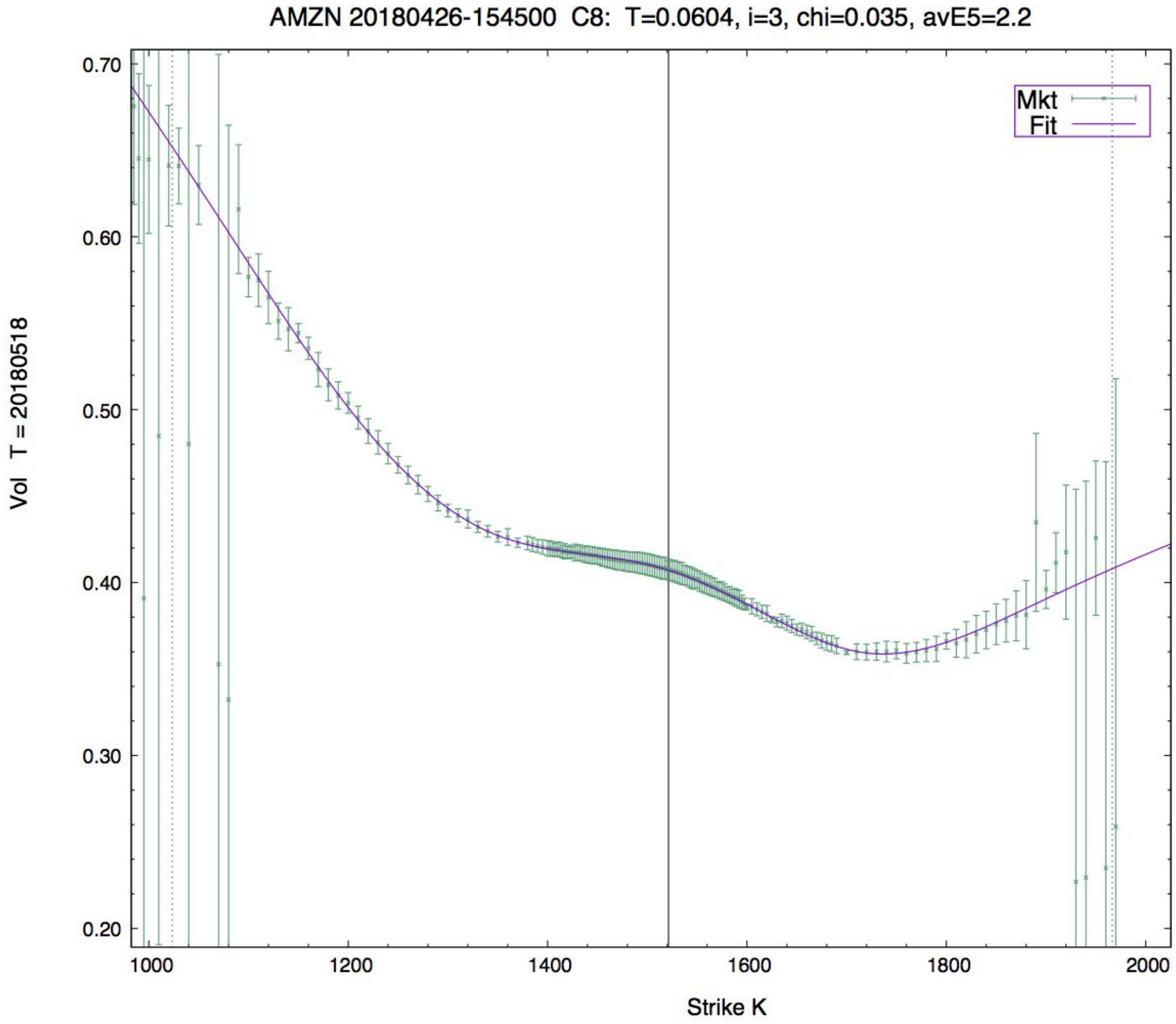
Most negative c2 ever!



AMZN 2018-04-26

earnings day

Vol fit for 2nd term, i=1, K-space



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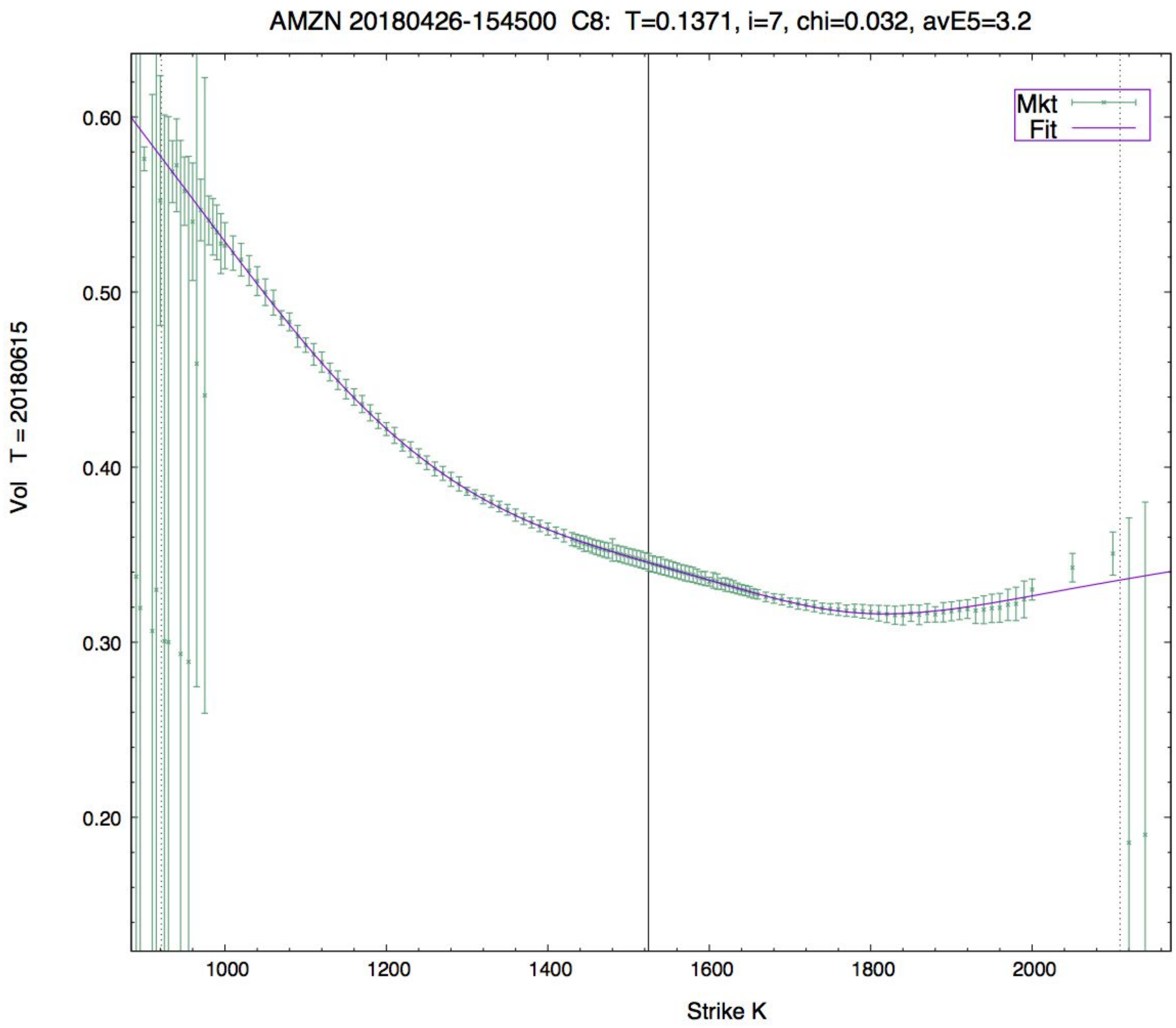
AMZN 2018-04-26
earnings day

Vol fit for 4th term, i=3, K-space

Still negative c2!

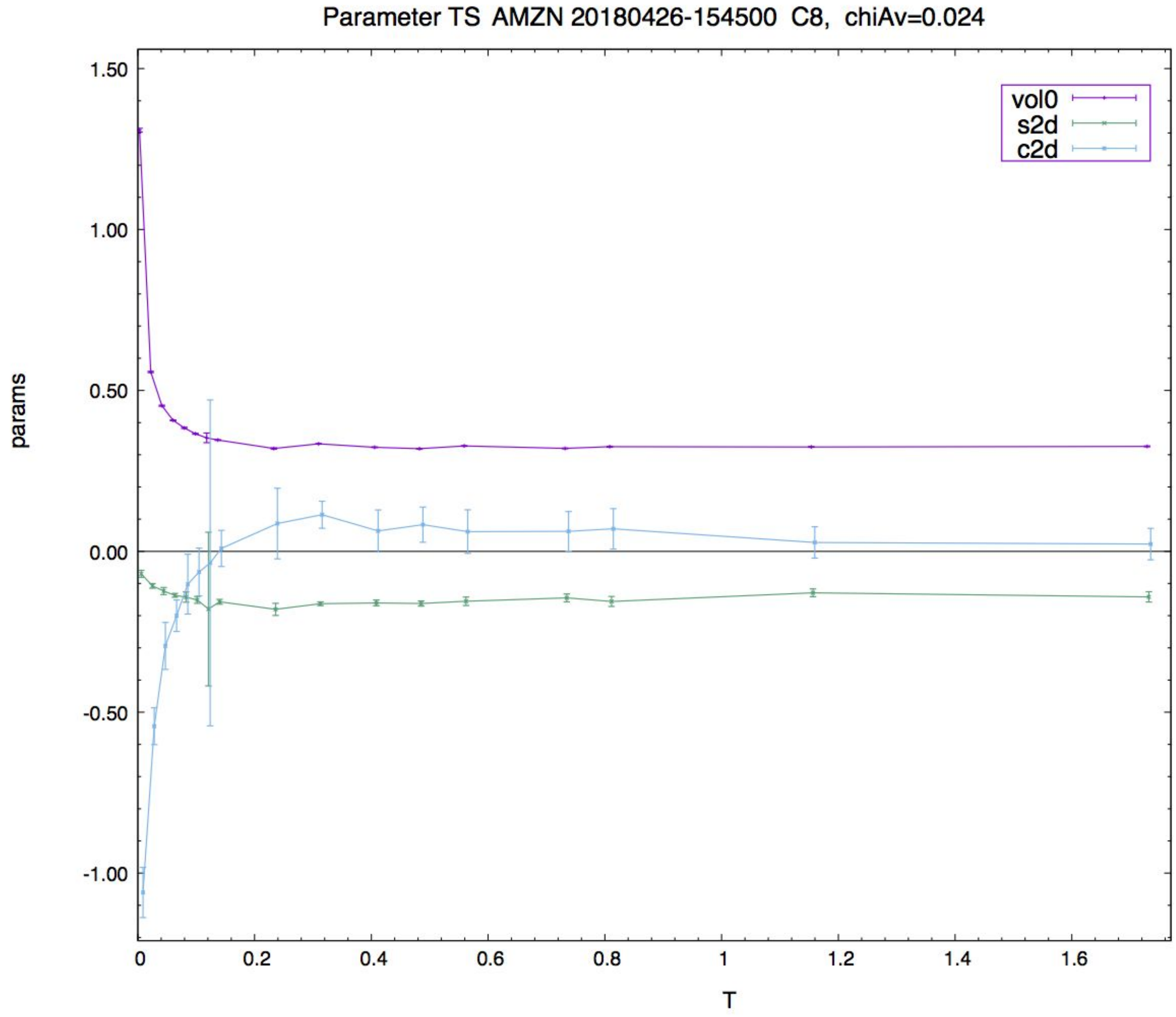


AMZN 2018-04-26
earnings day

Vol fit for 8th term, i=7, K-space

Flat around ATM now, c2≈0.

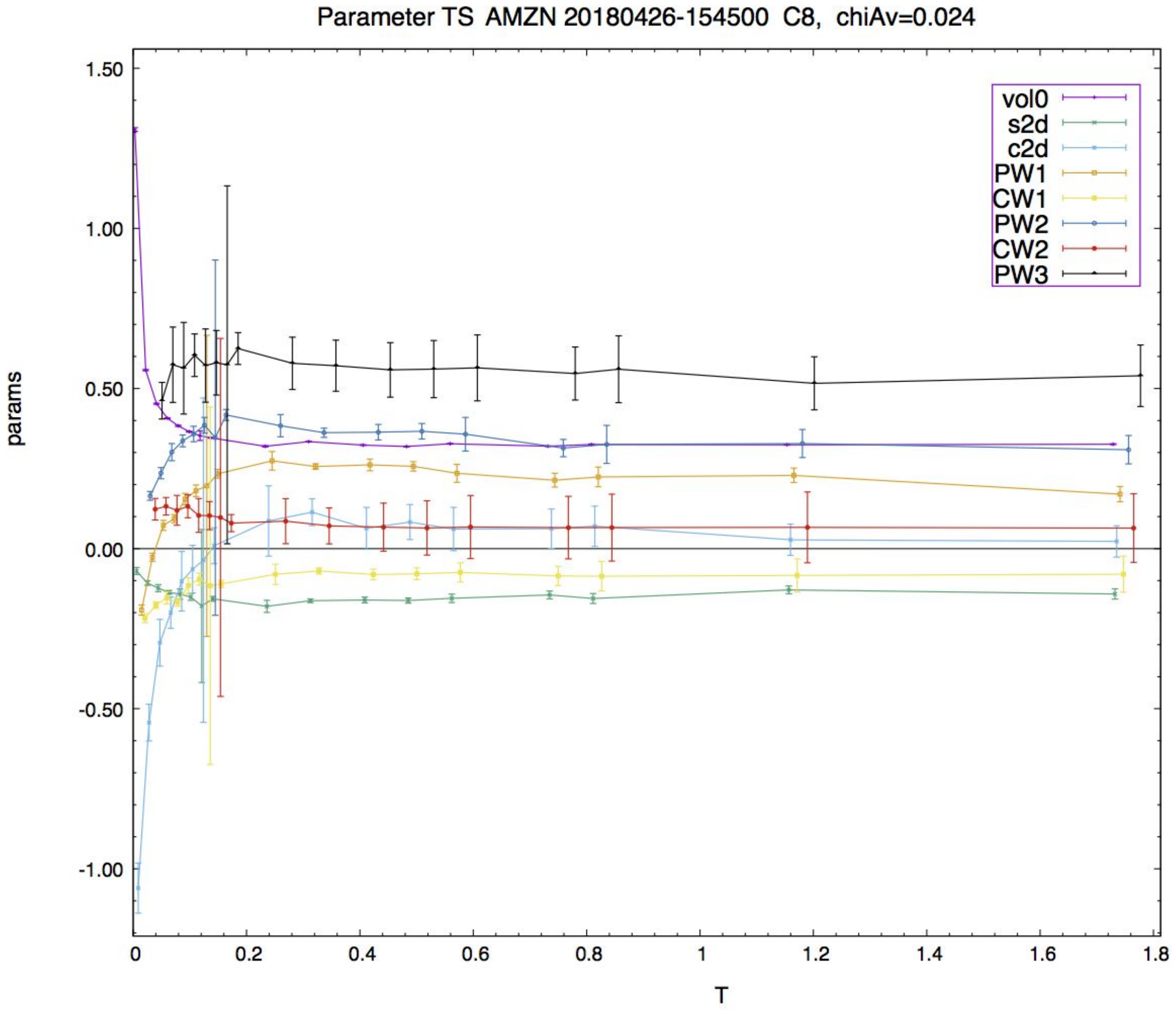
Use C10 if you worry about far wings...



AMZN 2018-04-26 earnings day

C8 parameter term-structure, first 3

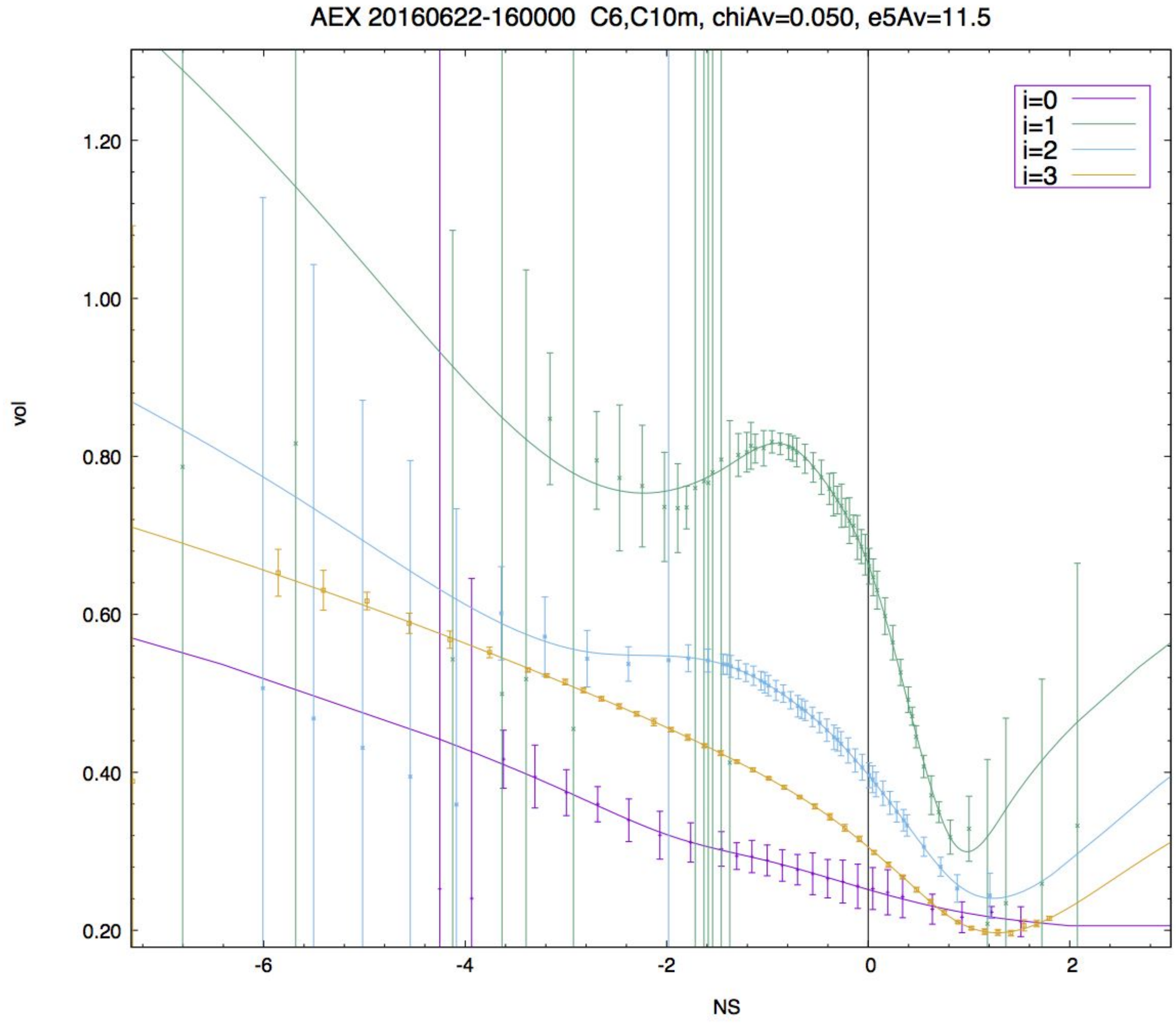
Essentially flat shape params after 3m



AMZN 2018-04-26 earnings day

C8 parameter term-structure

Essentially flat shape params after 3m



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Fitting **AEX** on day before Brexit (2016)

Vol vs NS

AEX on day before Brexit:

T=2d, vols and implied density

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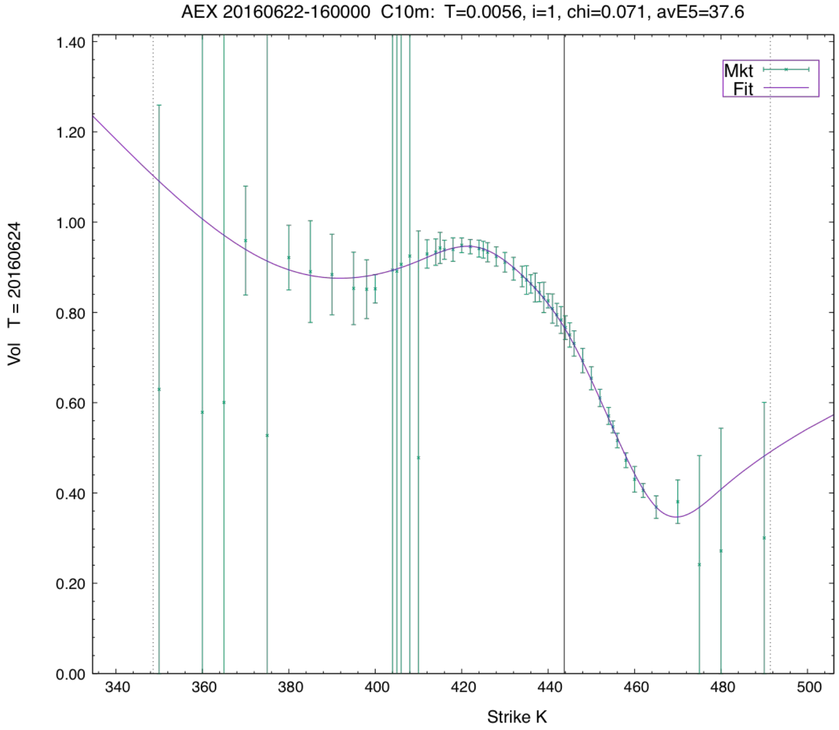

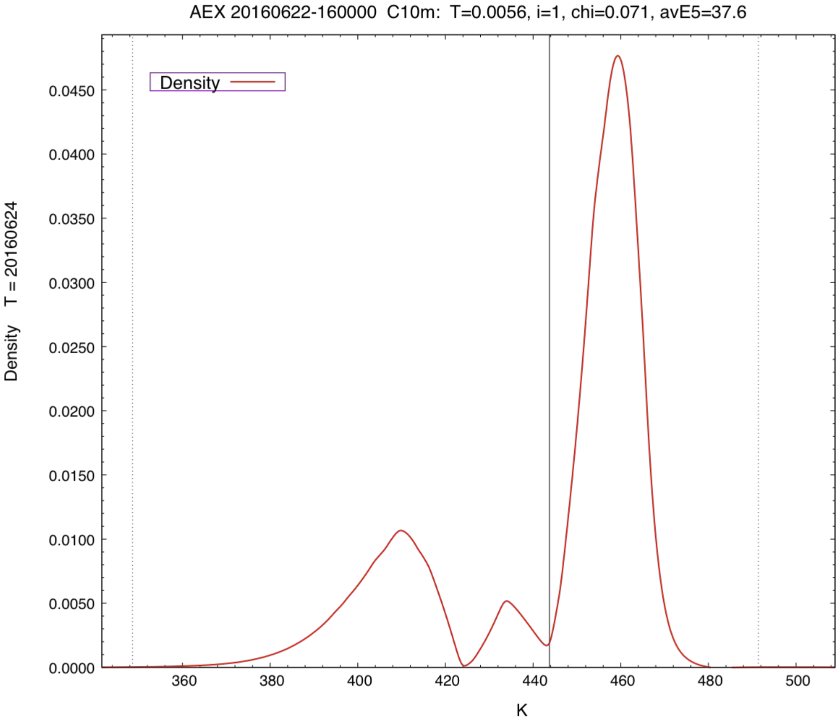

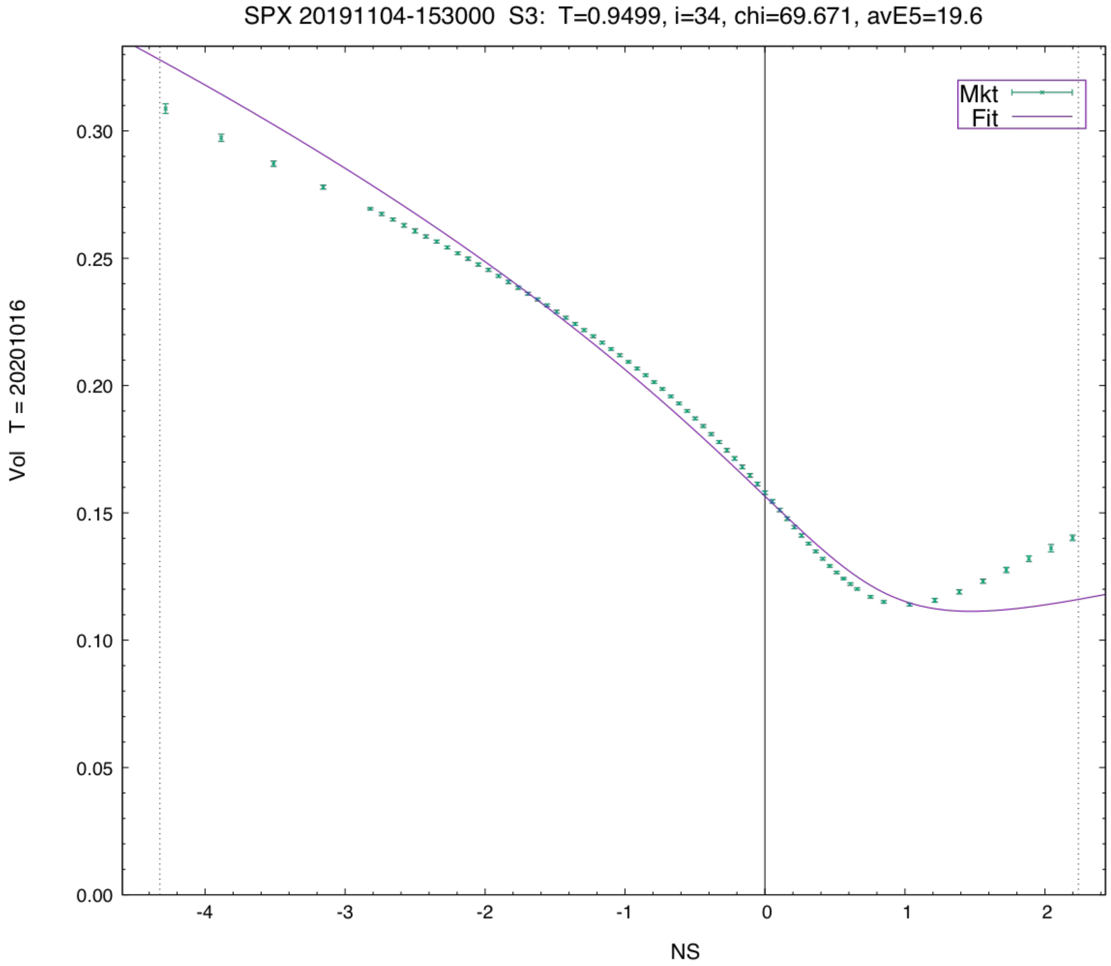

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Can non-W shapes be fitted with simple curves?

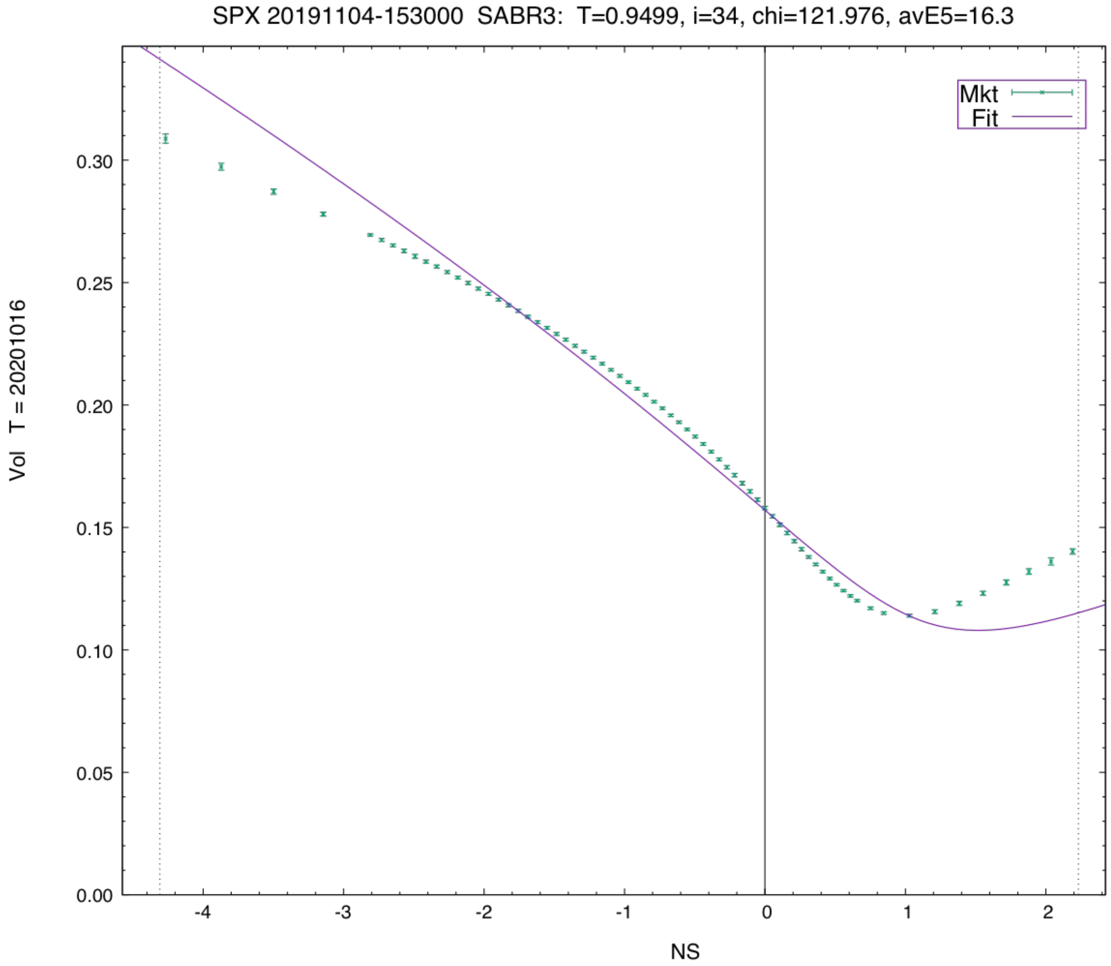
No, not for liquid names!

SPX 20191104

SSVI / S3 fit, i=34, T=0.95y

This is a lousy fit even over a small range…

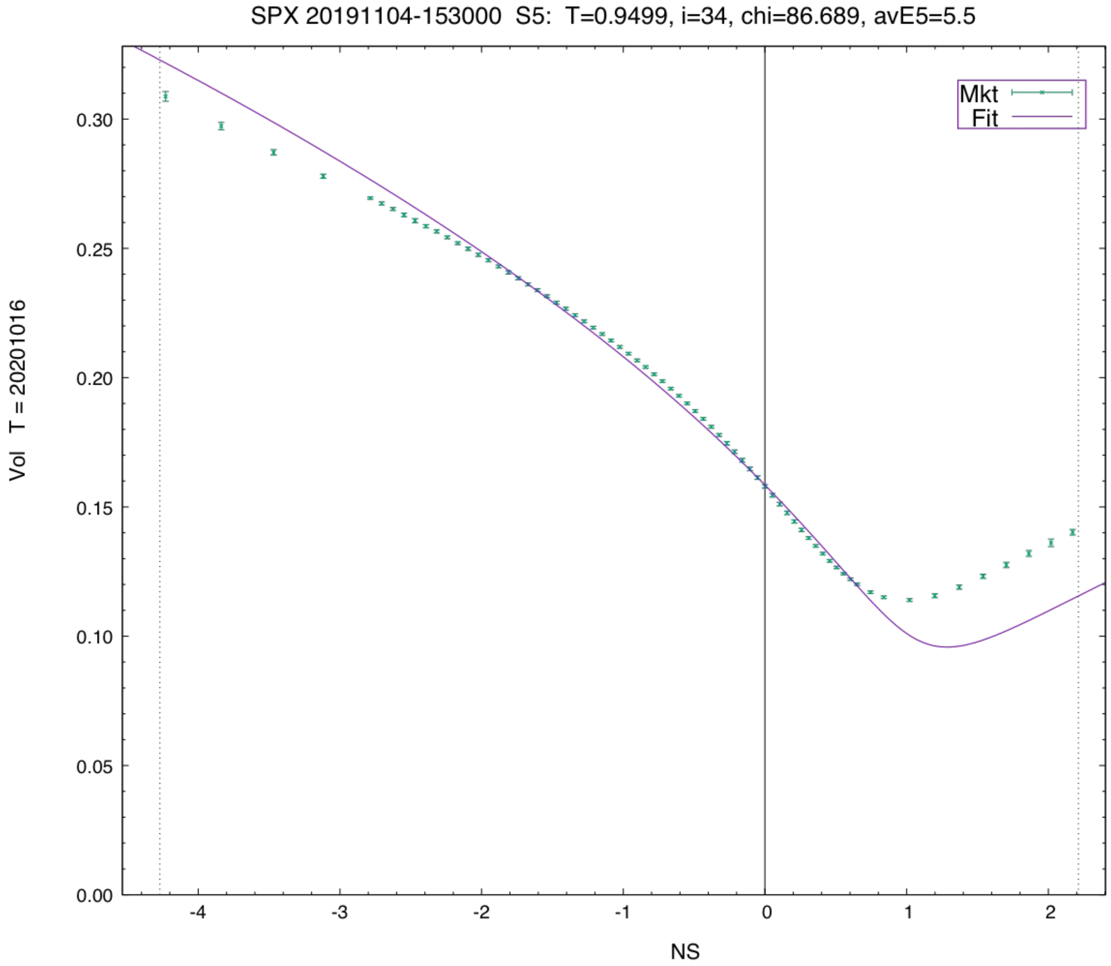
… even though shape looks “simple” (c2>0) and this is a supposedly easier longer term…



SPX 20191104

SABR fit, i=34, T=0.95y

This is a lousy fit even over a small range…

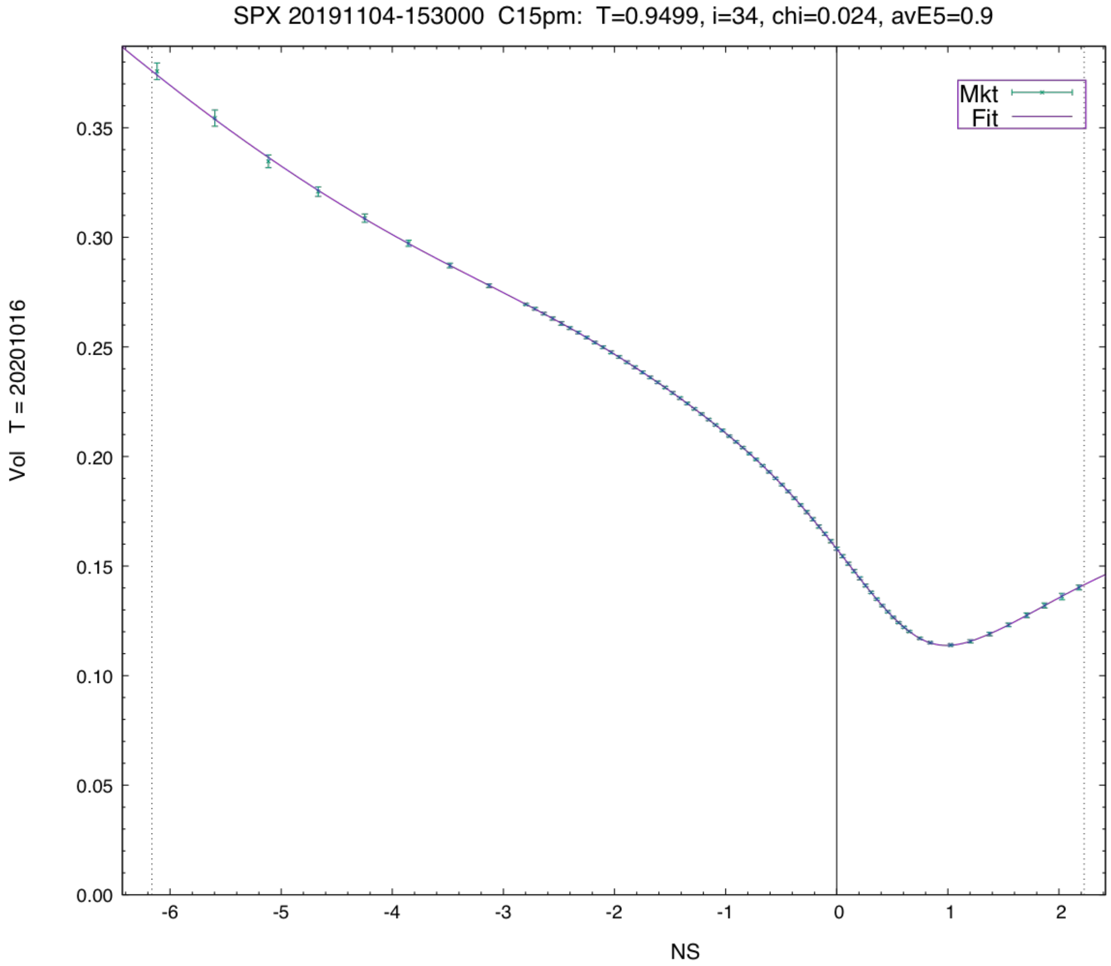


SPX 20191104

SVI / S5 fit, i=34, T = 0.95y

This is still a lousy fit even over a small range...

Ditto for T = 2y ....



SPX 20191104

C15 fit, i=34, T = 0.95y

This is a great fit over a wide range, and can't be improved w/o over-fitting...

chi2 is 5000x smaller!

What is a “good” vol curve and fit ?

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- The academic literature still has claims that e.g. SVI can fit SPX options.
- No... But how do we know what a “good” curve & fit is? Or a “good enough” one?
- **Curves** requirements:
  - Allow market vols to be fitted in arbitrage-free and **bias-free** manner.
  - Does this mean that fit has to go through all (inside) bid-ask spreads?
  - No, but has to be bias-free (on fraction of typical spread level) over time: requires very flexible curves
  - Usually 99.5% to 100.0% of theos should be within bid-ask spread for liquid names (⇔ bias-free).
- **Fitter** requirements are mostly technical but crucial in practice:
  - Has to find global minimum of some suitable objective function in a fast and robust fashion.
  - Curves, Fitter & Priors interact when it comes to producing arbitrage-free and sensible results w/o over-fitting -- the statistically best fit of the market is almost never the best answer…
  - Avoiding butterfly & calendar arbitrage in a fast and sensible manner require quite different algos.
- Simple curves like S* can definitely **not** fit liquid names in a **bias-free** manner.

Examples: Stable, Bias-Free, Arb-Free Fits

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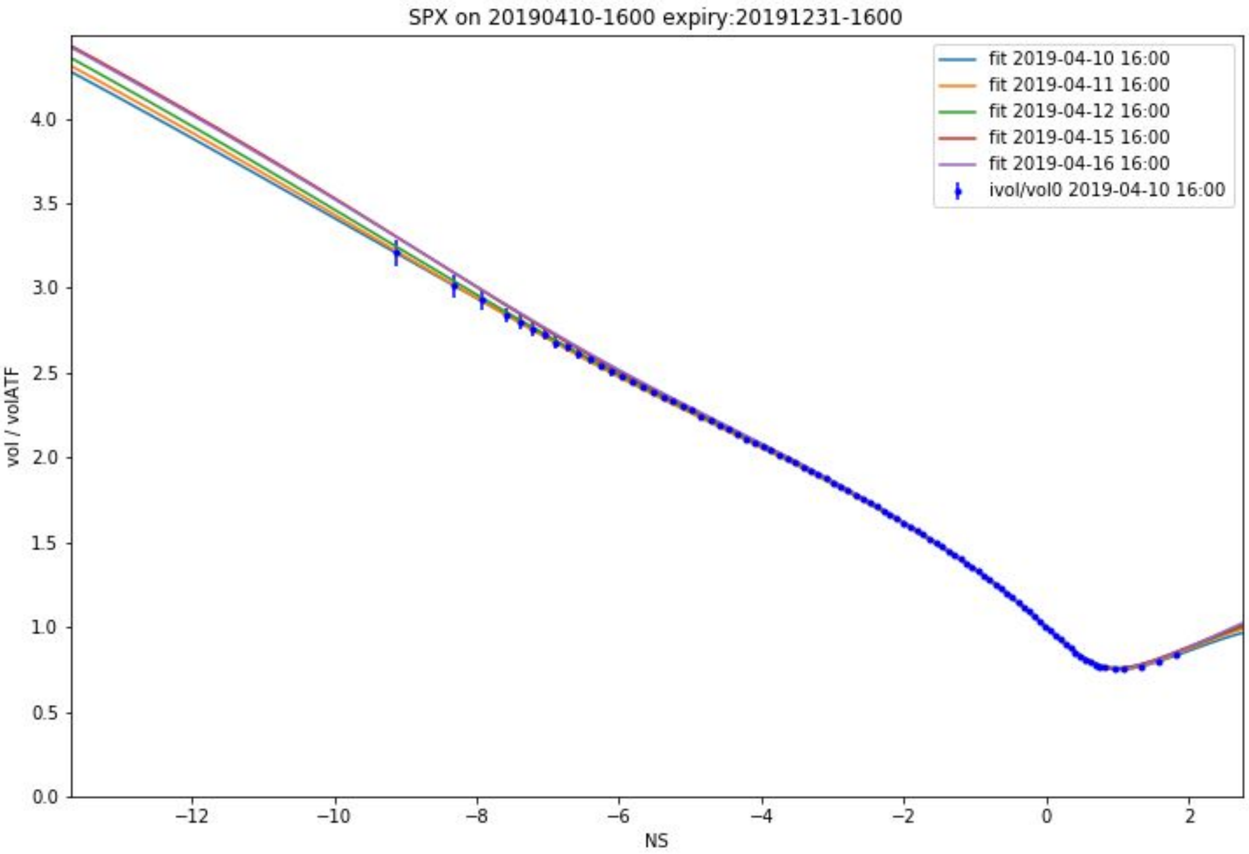
- Stability: Shape Curves tend to be extremely stable.
    - Intra- and extra-day unless “something really happens”...
- Good fits are “better than the market”.
- To avoid calendar arbitrage, the fitter has to tie together different terms, separate term-by-term fits will never work...
- Let’s look at some examples...



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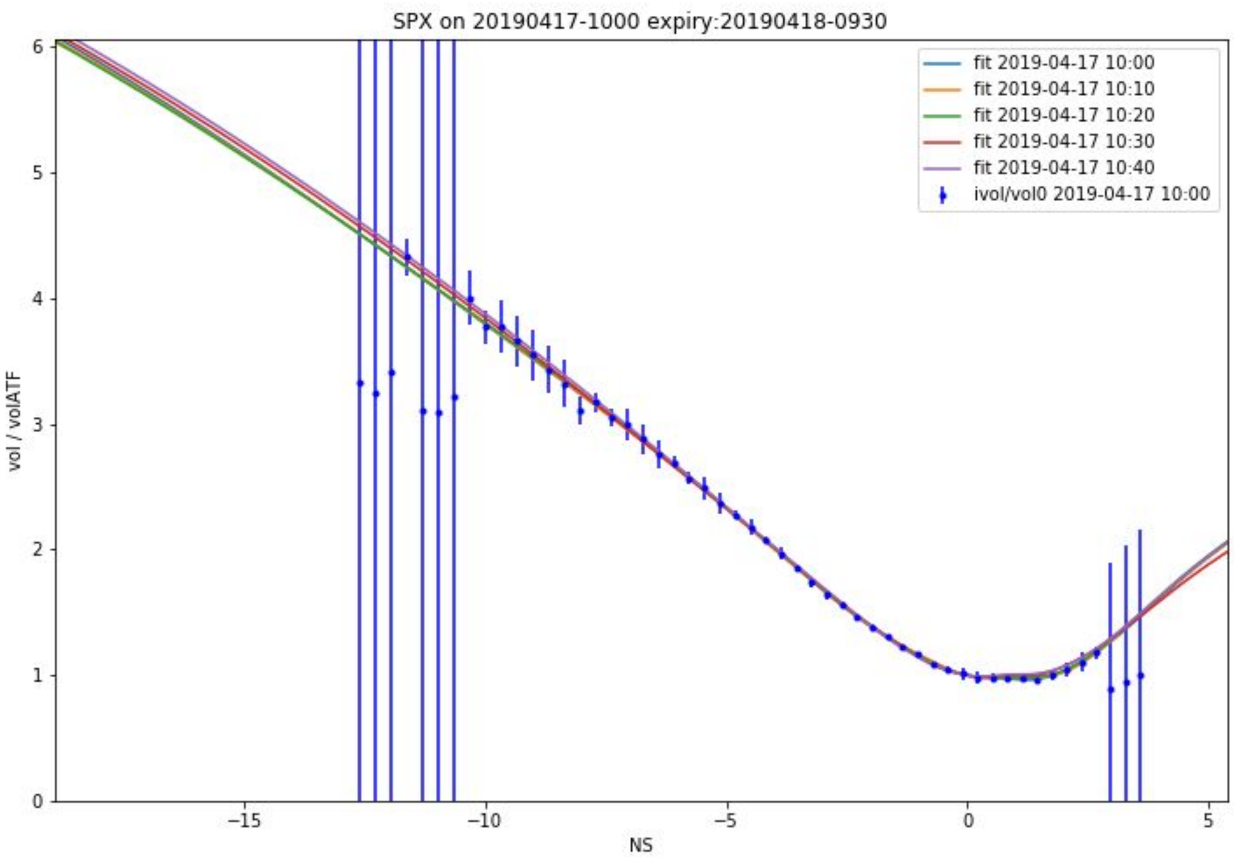
SPX 20190410 Shape Curve T = 0.7y

Example of fitter and shape **stability** -- even for **snapshot** fitting EOD over many days!

(No temporal filtering used here…)

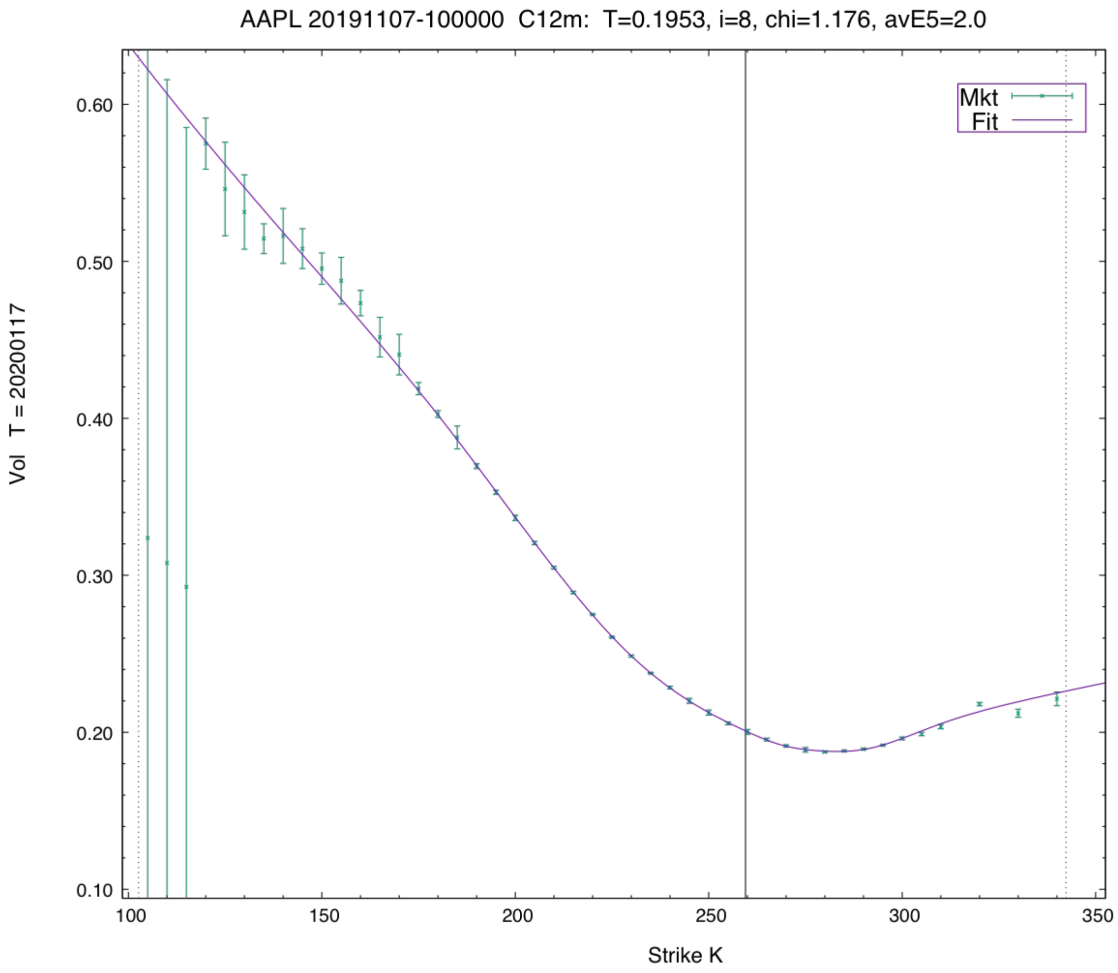


SPX 20190417 Shape Curve T=1d

Example of fitter and shape **stability** -- **snapshot** fitting every 10 minutes for T=1d.

(No temporal filtering used here...)

No floppy wings!

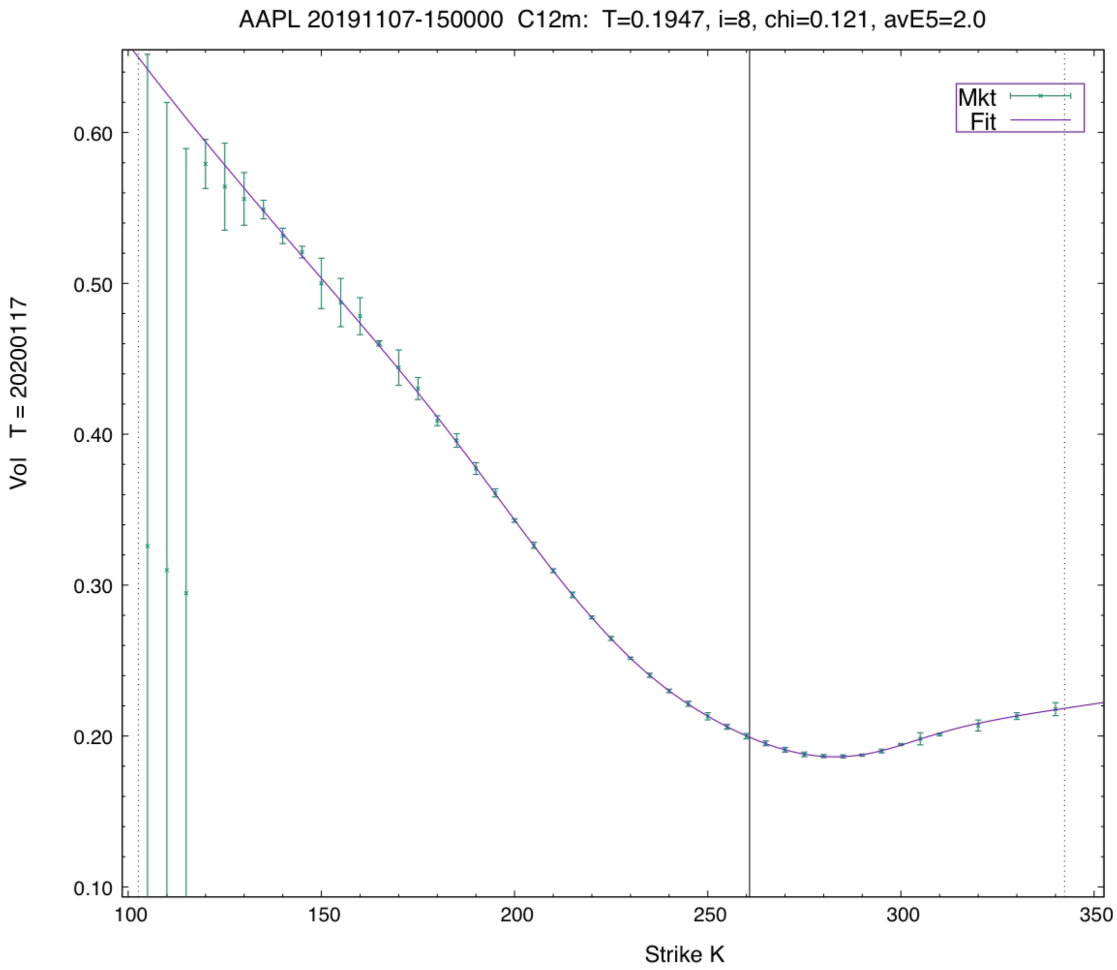


AAPL 20191107

Fit misses some strikes in CW and PW.

Should we trust market or fit?
The fit looks biased.

Let's look later in day....



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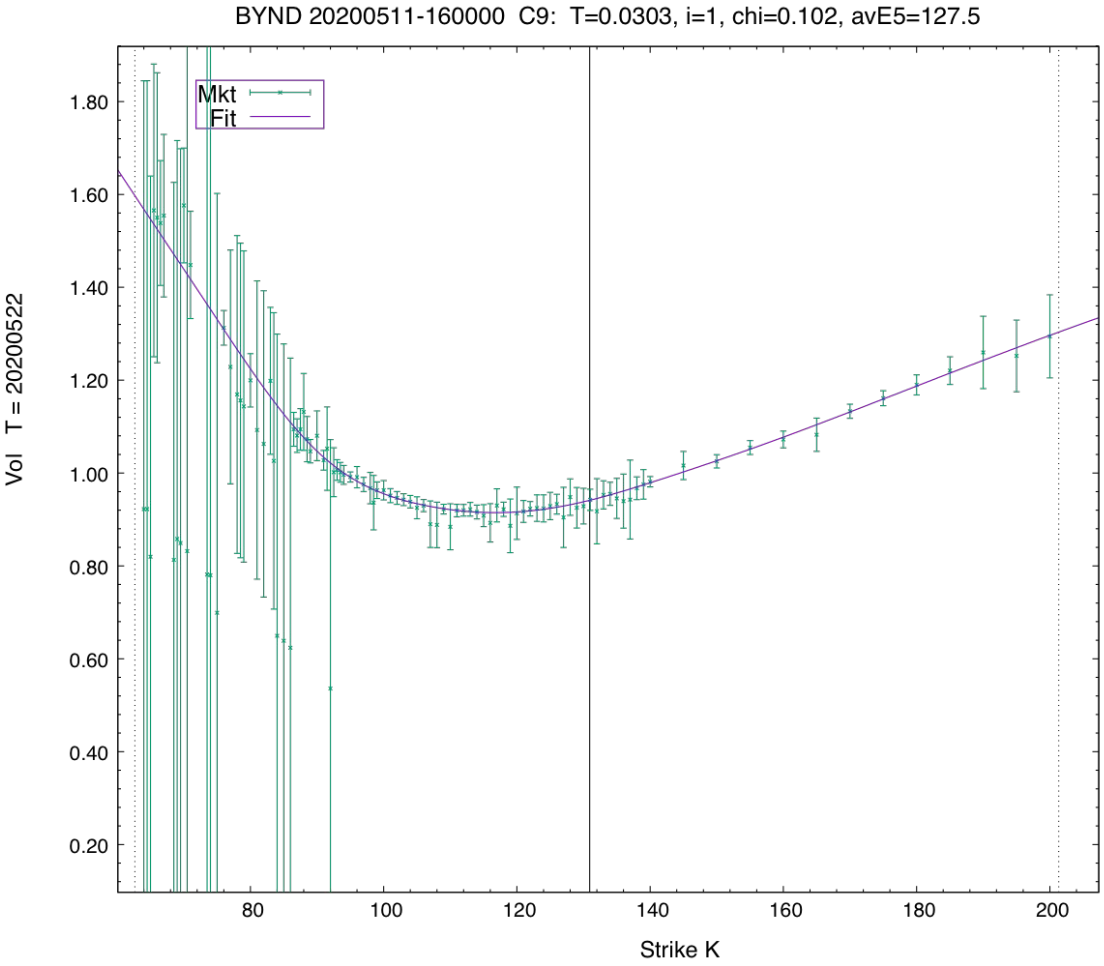
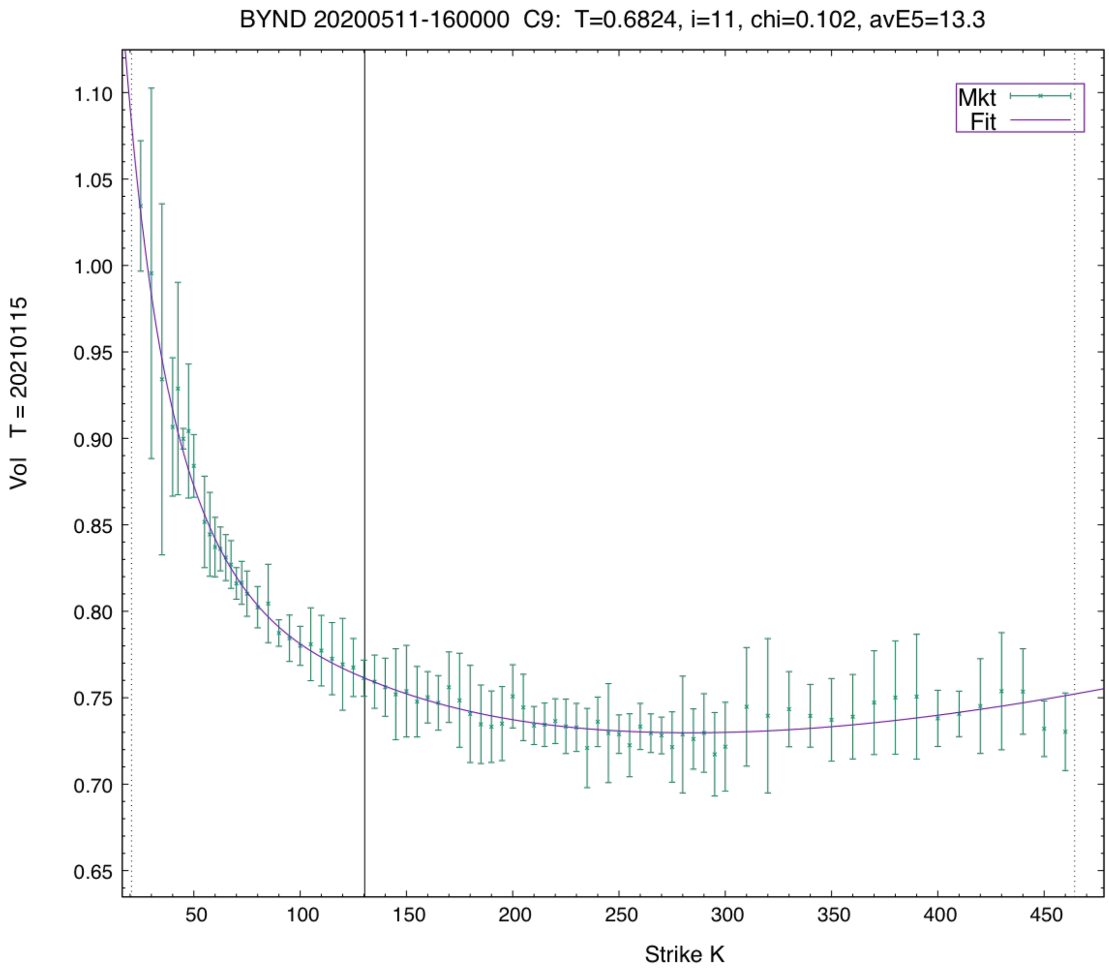
AAPL 20191107

Looks like fit was right…



BYND 20200511

Do not trade off mids…



VOLA DYNAMICS
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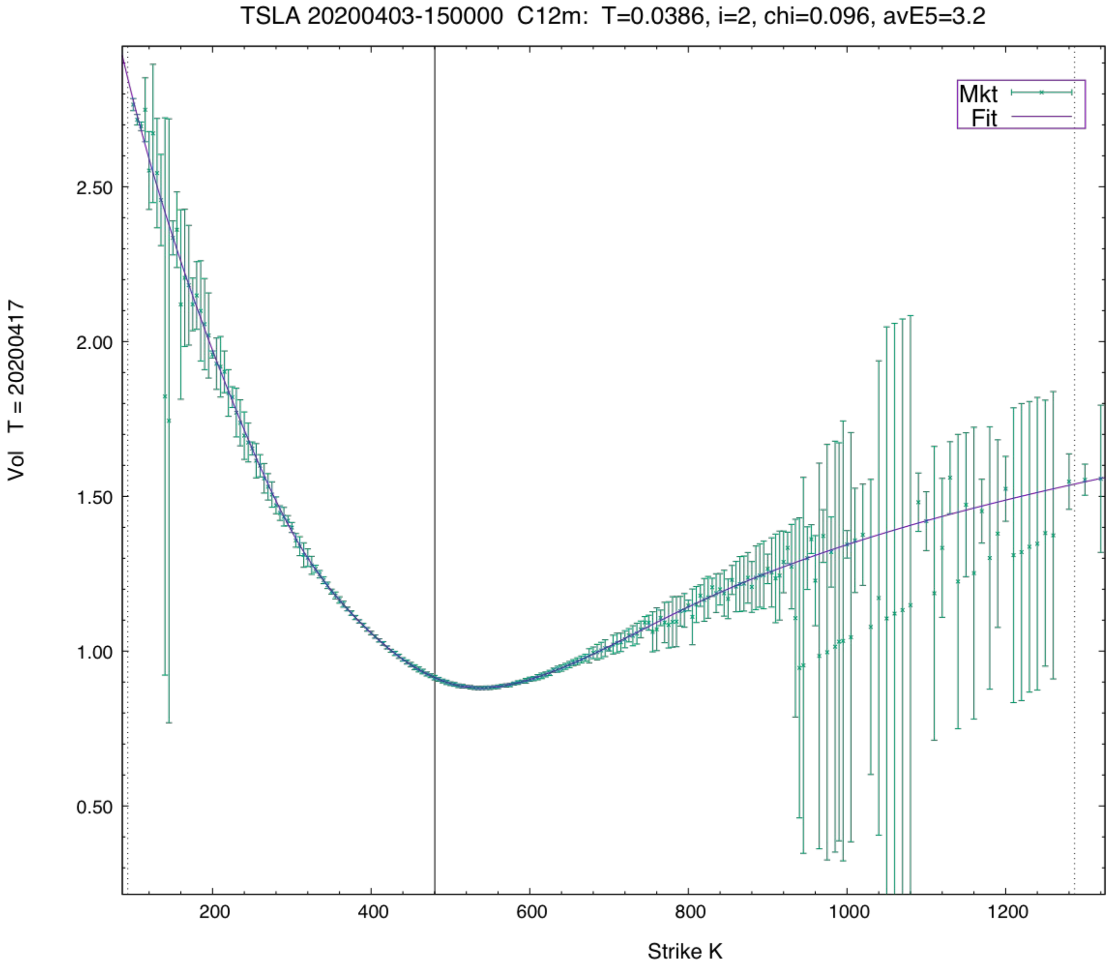

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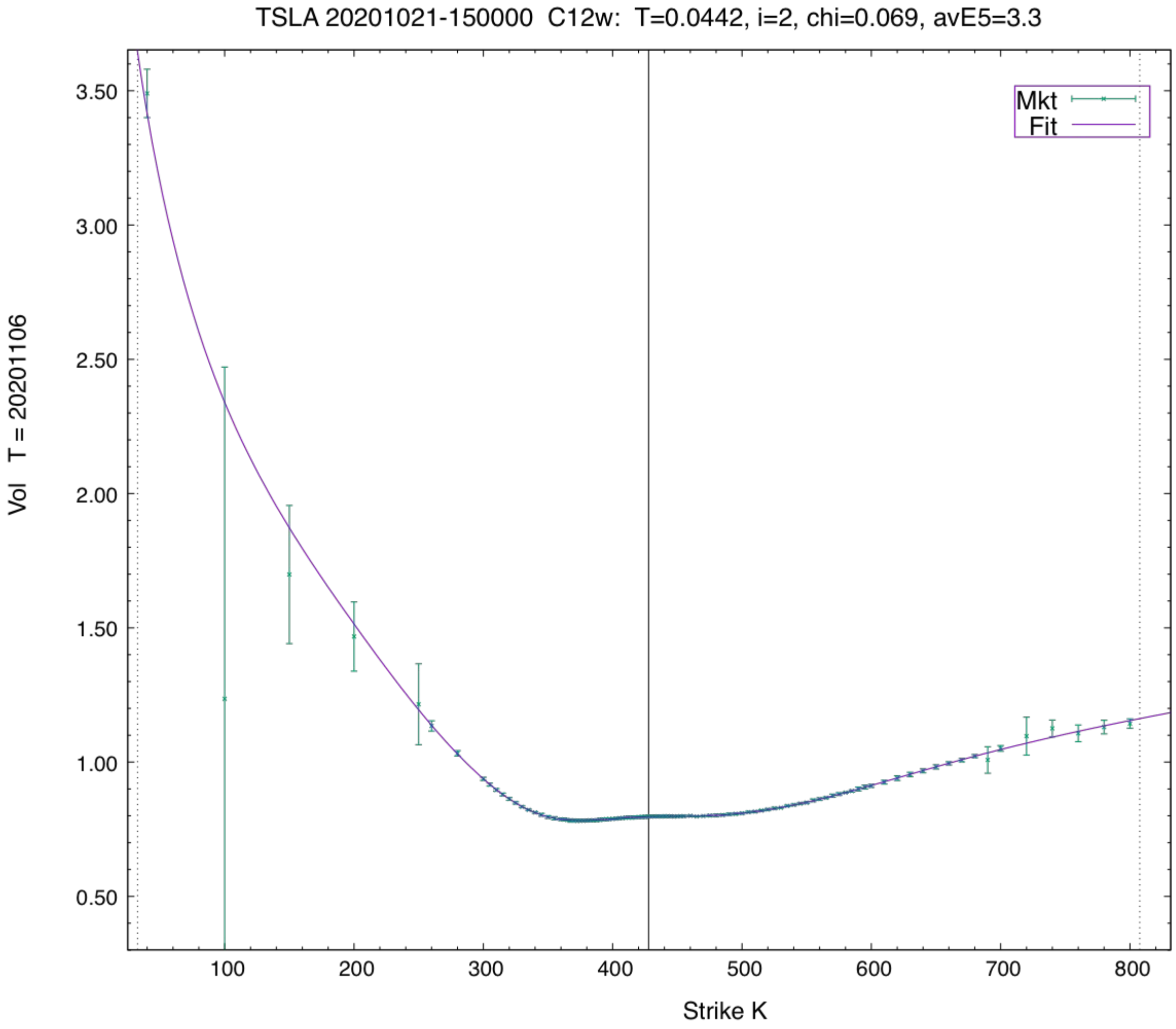
TSLA 20200403

Do not trade off mids…

NOTE: Strike range > 10x



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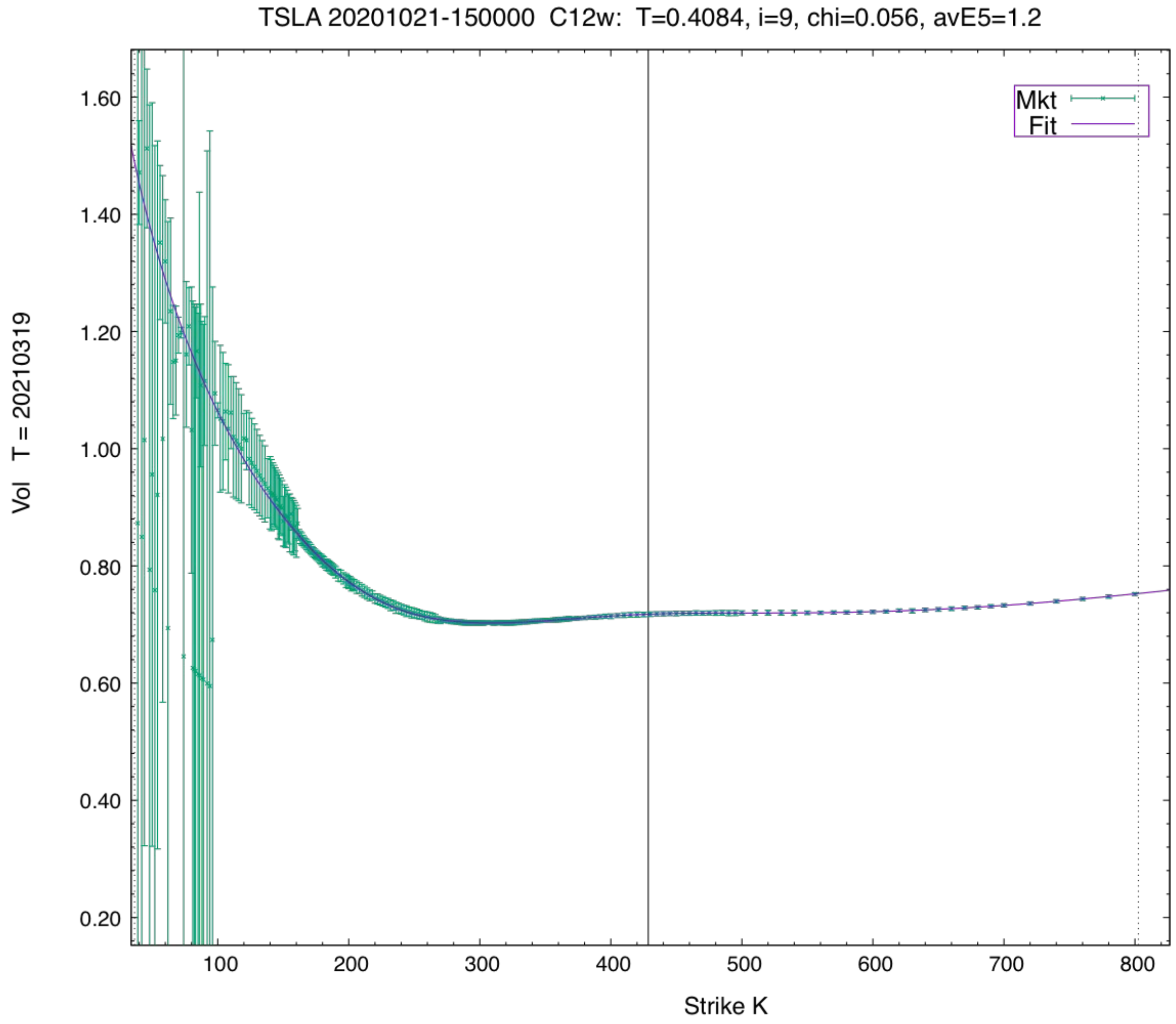
TSLA 20201021

Different day -- very different shapes and spreads...

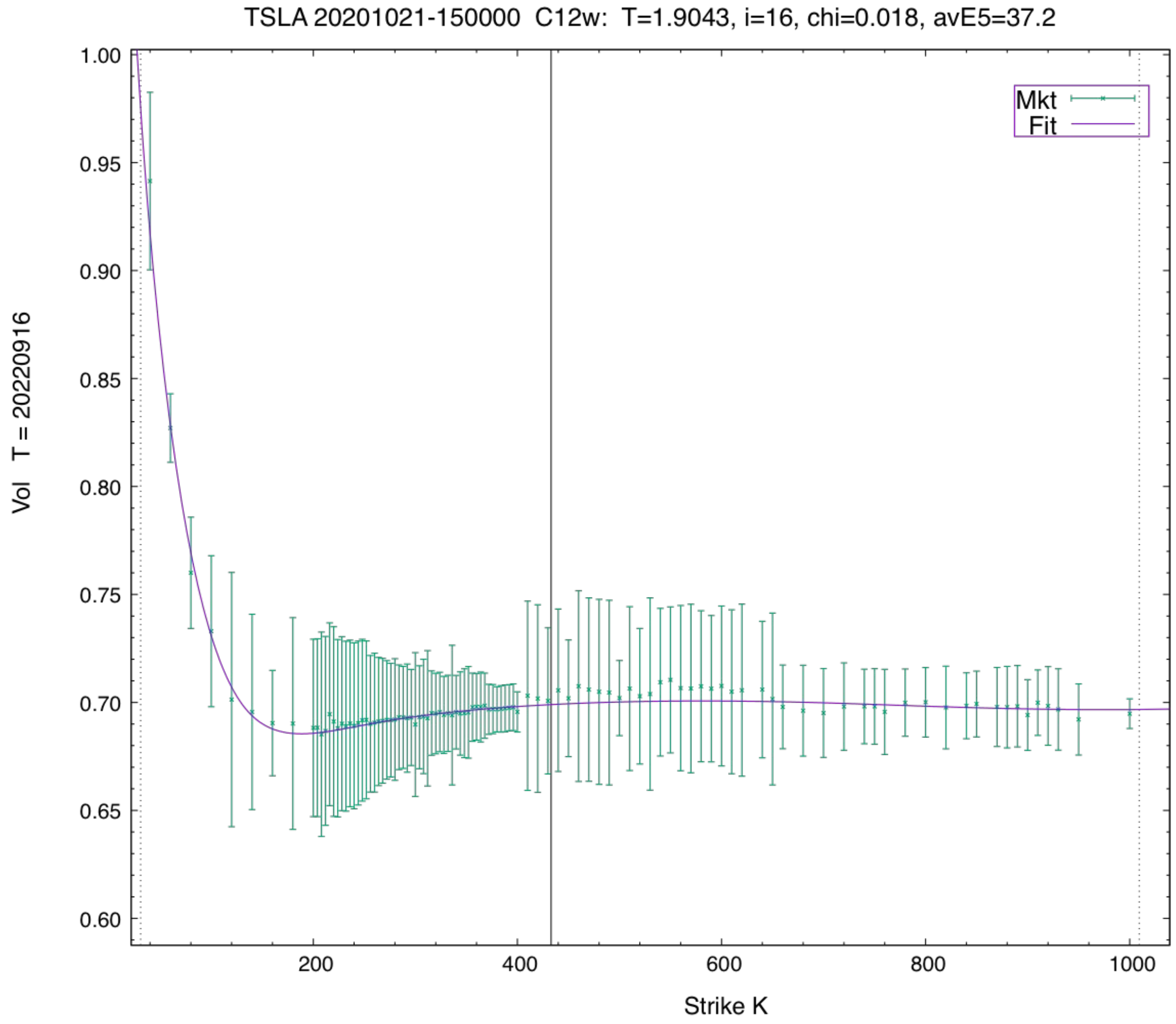
NOTE: Strike range > 10x



TSLA 20201021

Is the market using the Merton model ?

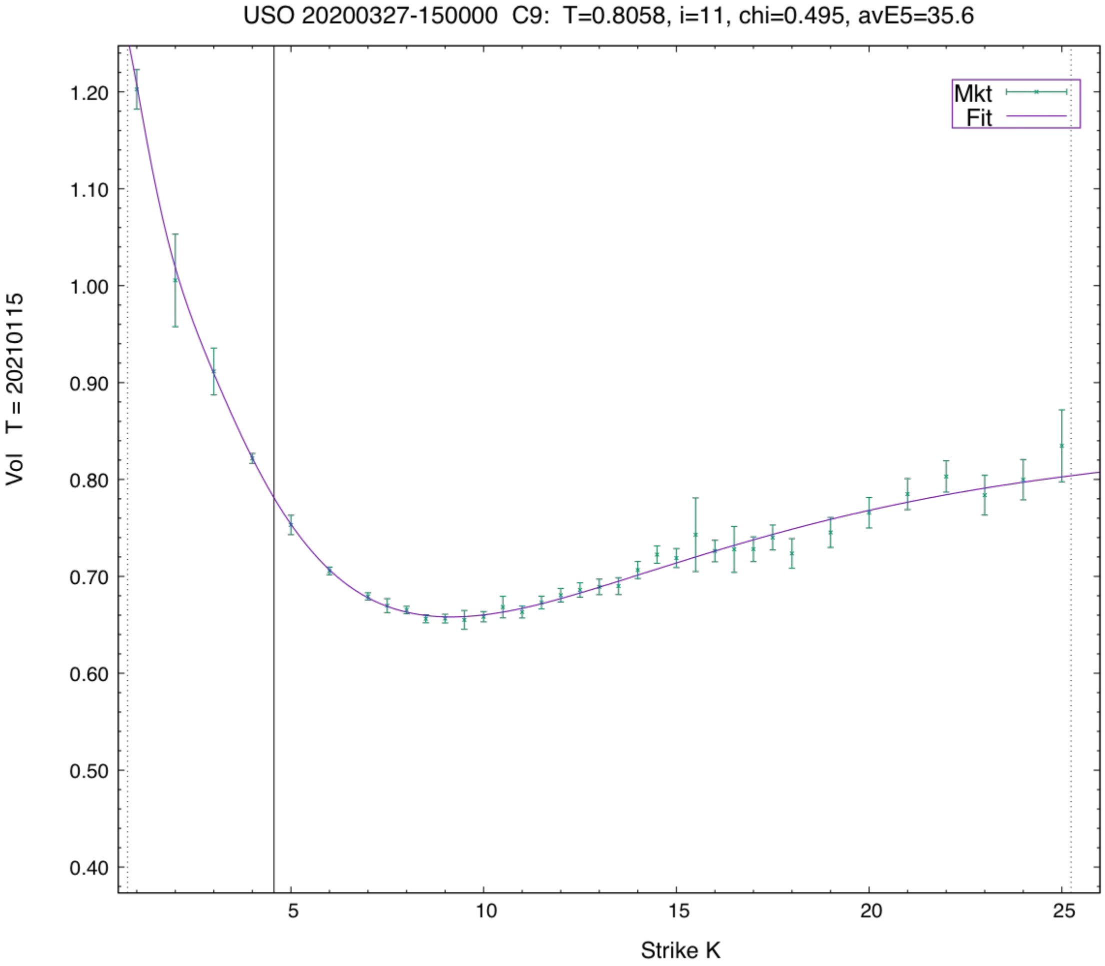
NOTE: Strike range > 10x



TSLA 20201021

Is the market using the Merton model ?

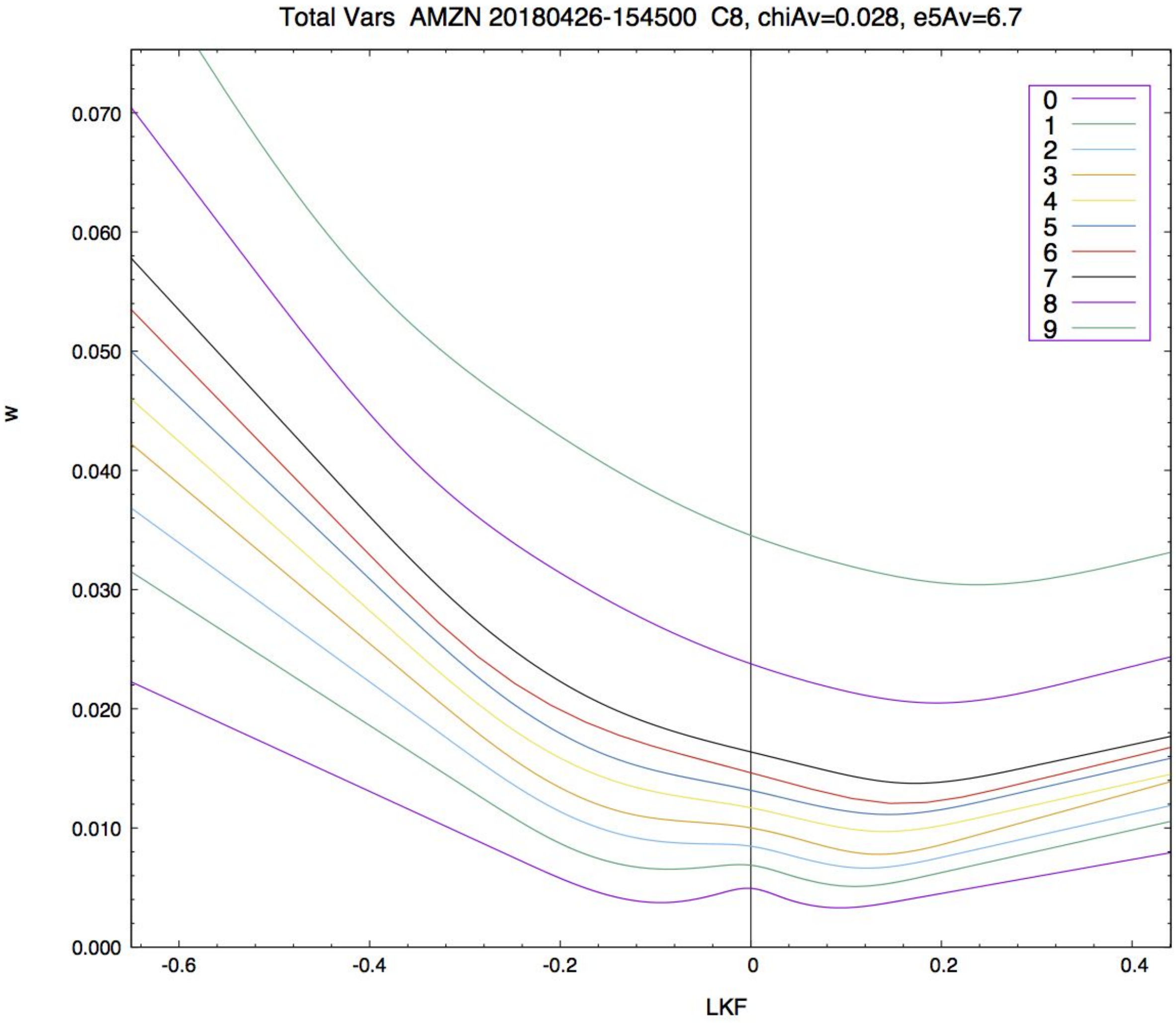
NOTE: Strike range > 10x



USO 20200327

Do not trade off mids…

NOTE: Strike range is 25x



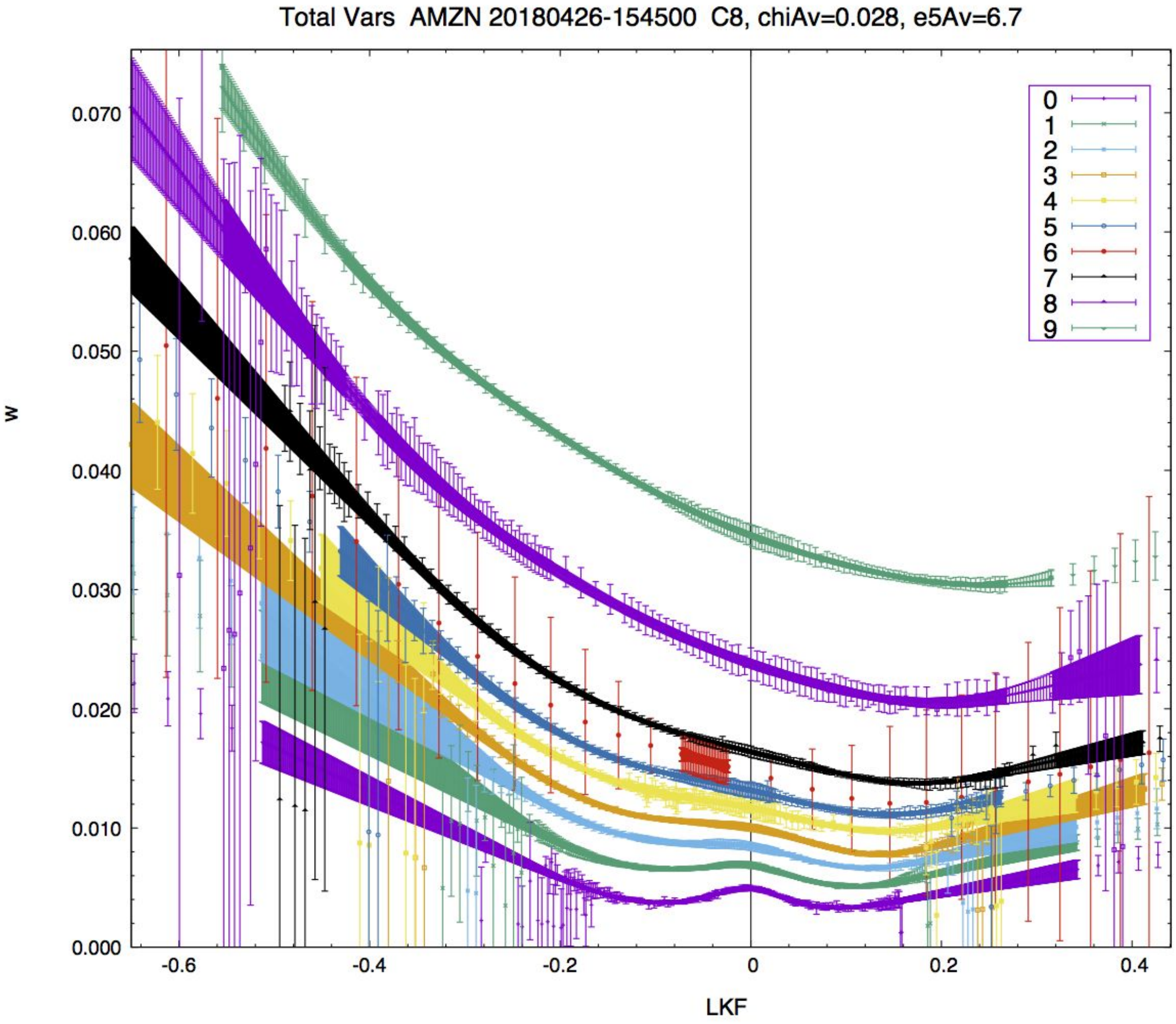
AMZN 2018-04-26 earnings day

C8 total variance plot

First 10 terms

No calendar arbitrage! (Or butterfly...)

Interesting Thursday: Earnings, new weekly listed (i=6), etc.



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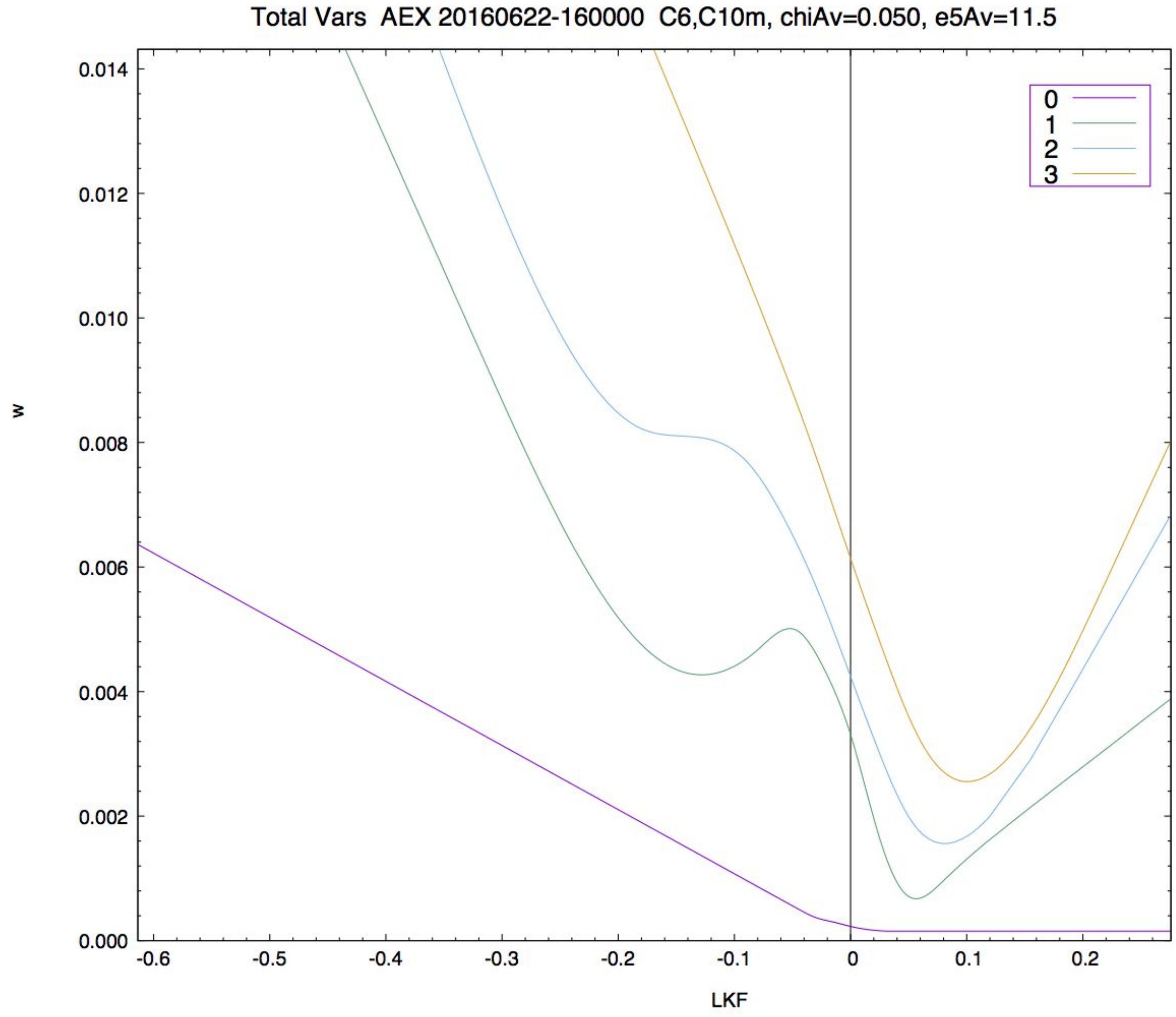
AMZN 2018-04-26 earnings day

C8 total variance plot

First 10 terms, with errors bars

Interesting Thursday: Earnings, new weekly listed (i=6), etc.



VOLA DYNAMICS
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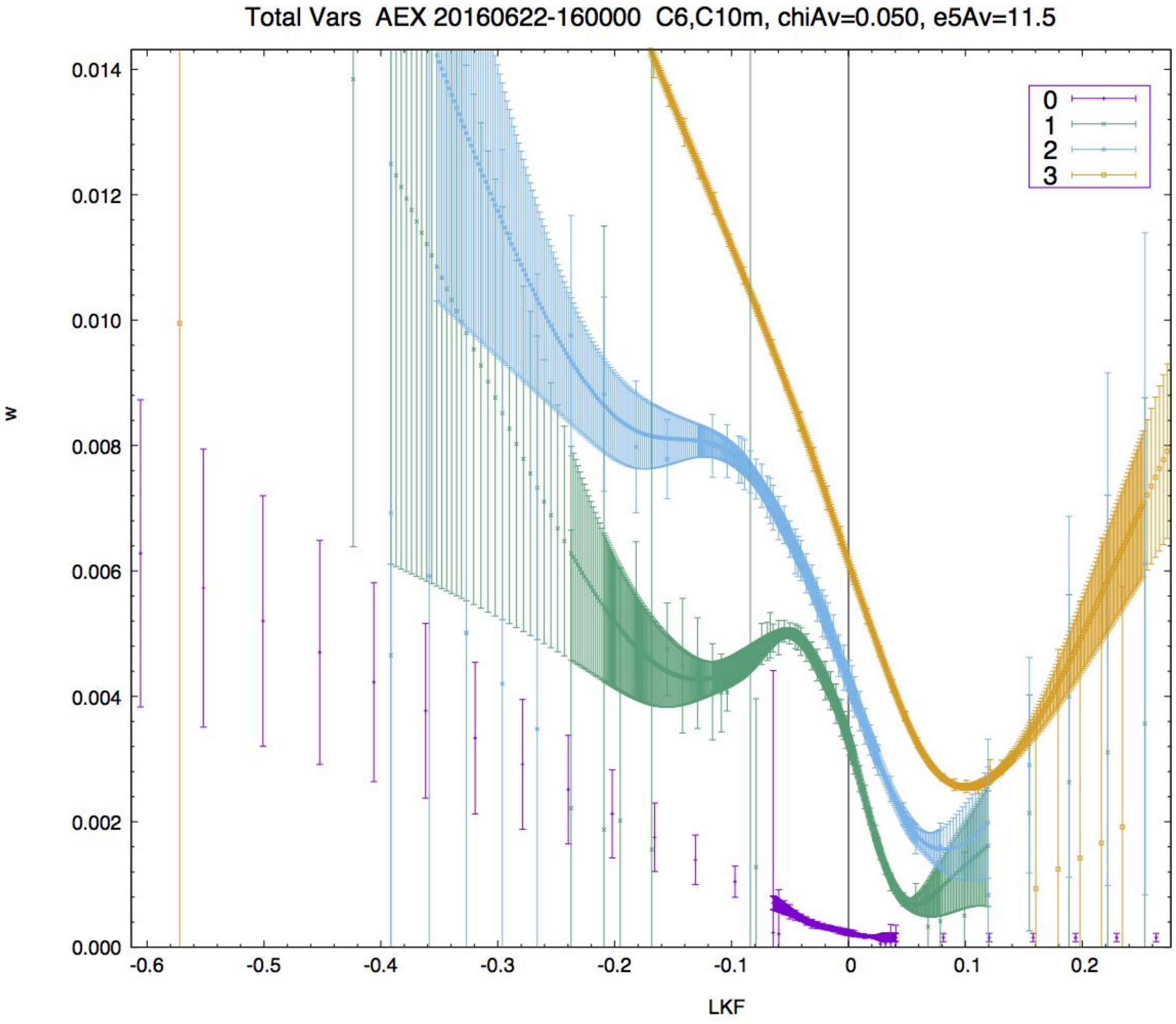
Fitting **AEX** on day before Brexit

Total Var plot



VOLA DYNAMICS

Analytics for Options Trading

Fitting **AEX** on day before Brexit

Total Var plot

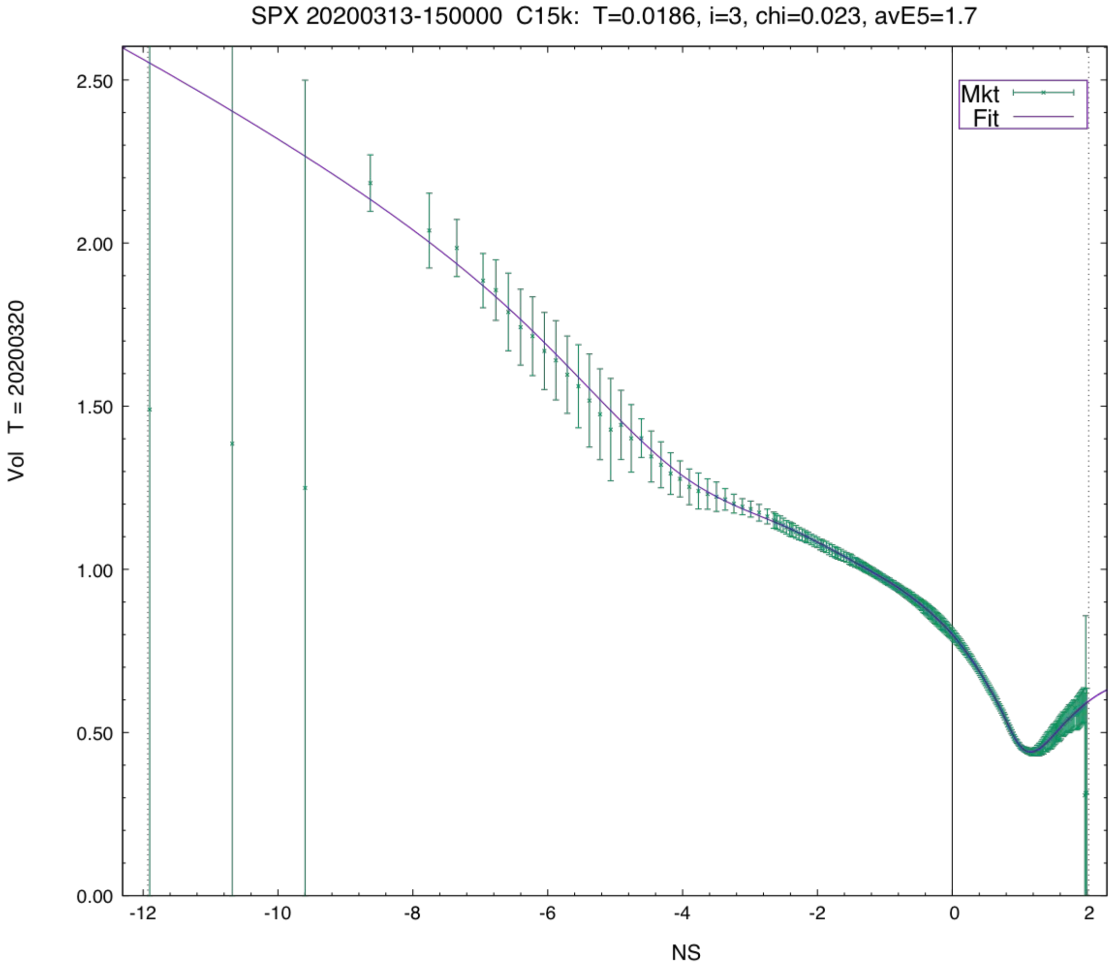
with error bars

Curve Statistics for the OPRA Universe in 2020

- There are 4300 names in OPRA (Nov 2020). We find, roughly, for bias-free fits:
  - 3000 (70%) can be fit with S3 (aka SSVI).
  - 300 (7%) can be fit with S5 (aka SVI).
  - 600 (14%) can be fit with C6.
  - The remaining 400 (9%) names require higher C* curves.
- S5 is usually a temporary stop on the way from S3 to C6 or other C* curves.
- Among the top 100 names, perhaps 20% can be fit with S3 or S5. (None in top 25).
- SPX complex requires 14-16 parameters for some terms to get bias-free fits of all options down to zero-bids. Big tech names & global indices require 9-12 param's.
- Significantly more C* curves are needed in 2020, 2021 than earlier:
  - The Robinhood/Reddit crowd (Nasdaq Whale, etc?) have bid up the call wings, PMs are protecting gains via puts: Both wings are wide with structure (and close to fly arbitrage...).

Recent Funky Vol Curves Shapes

- W-shapes around earnings have existed since 2005 or so (GOOG)
- Since about 2010 even indices can have negative ATF curvature ($c2 < 0$).
  - Usually around events like FOMC, elections, Brexit, etc.
- In the Trump/Reddit era there is an additional never-ending stream of potential events, and the shape landscape has been taken to a new level.
- The shapes correspond to specific expectations about future underlier distributions -- the market has become quite sophisticated about these.
- Let's look at some recent examples (LinkedIn posts have more details on SPX in March 2020, and GME in Jan 2021).

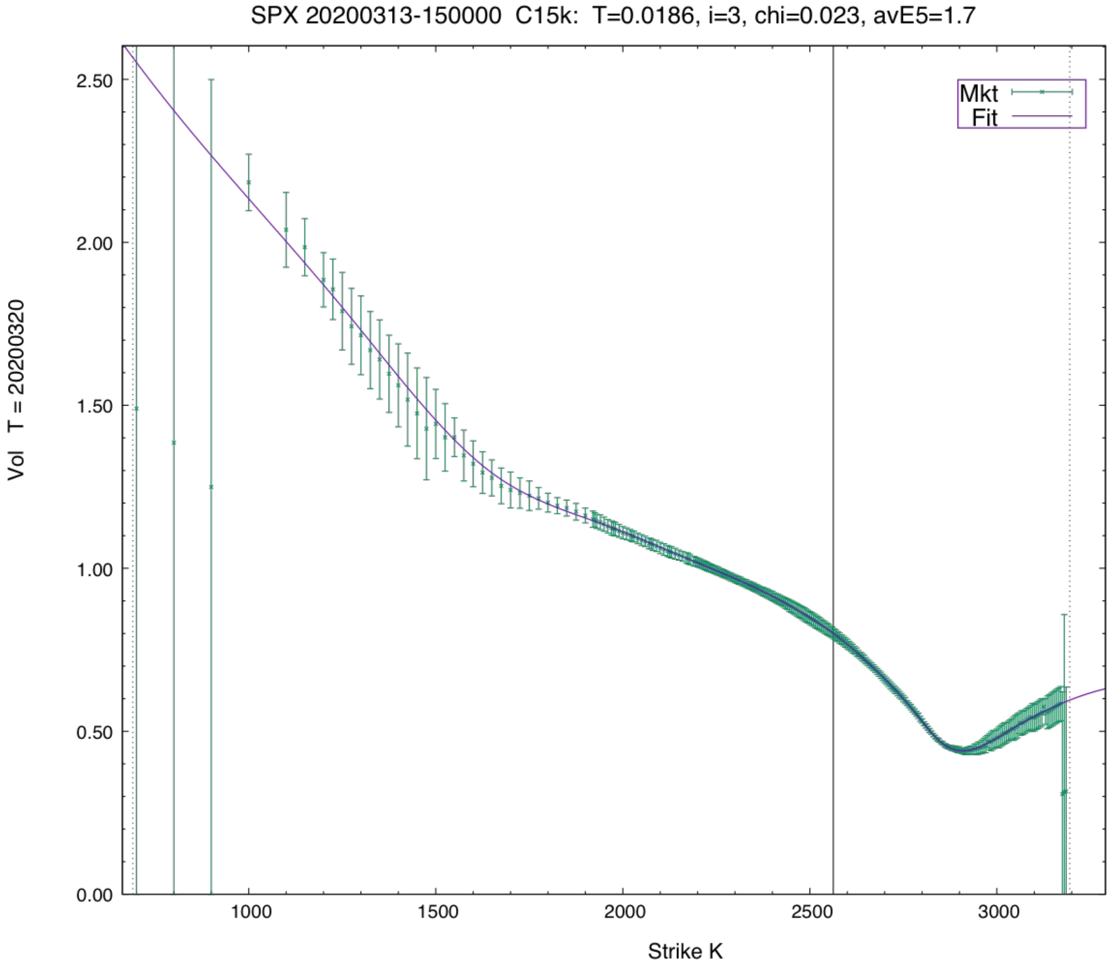


SPX 2020-03-13 15:00

C15K, T = 1w, in NS-space

Very compressed call wing in NS.

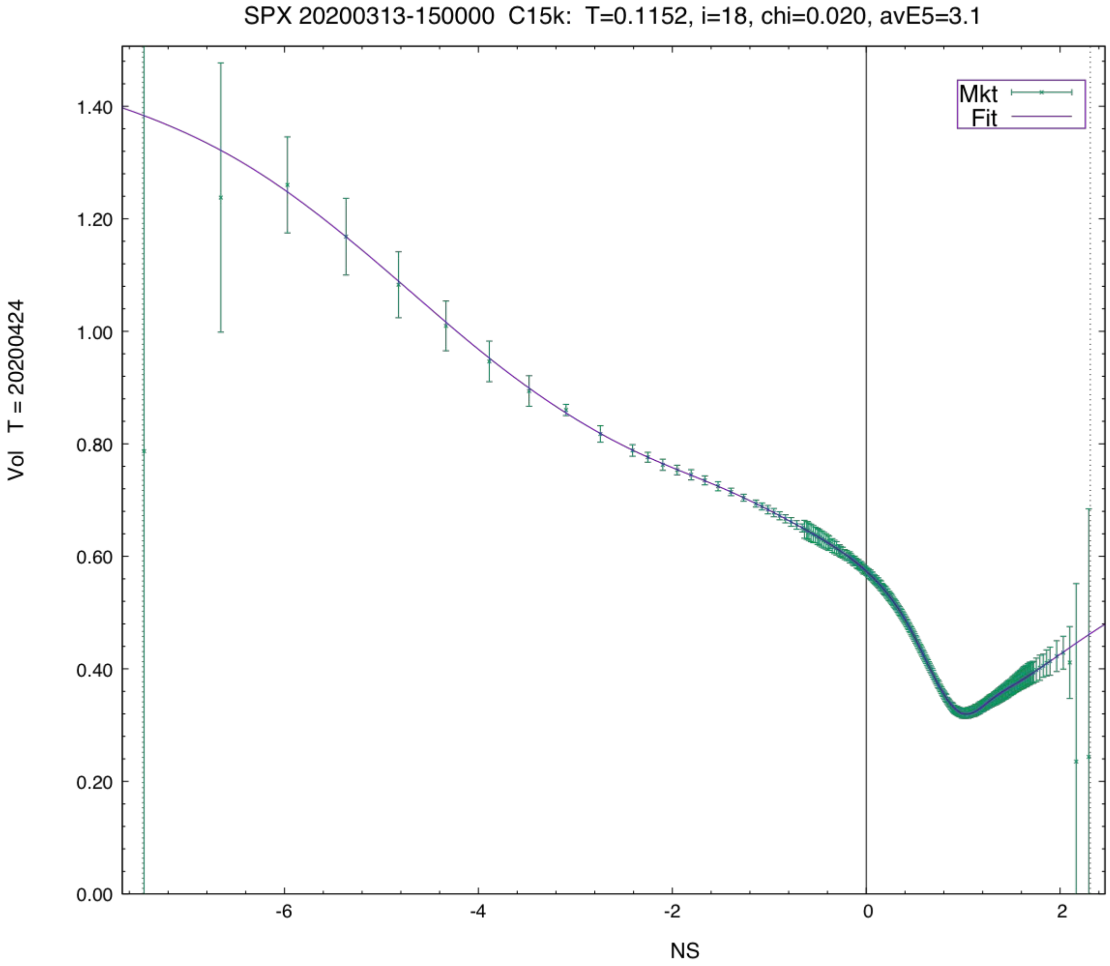
If fit followed market in put wing more closely there would be fly arb…



SPX 2020-03-13 15:00

C15K, T = 1w, in K-space

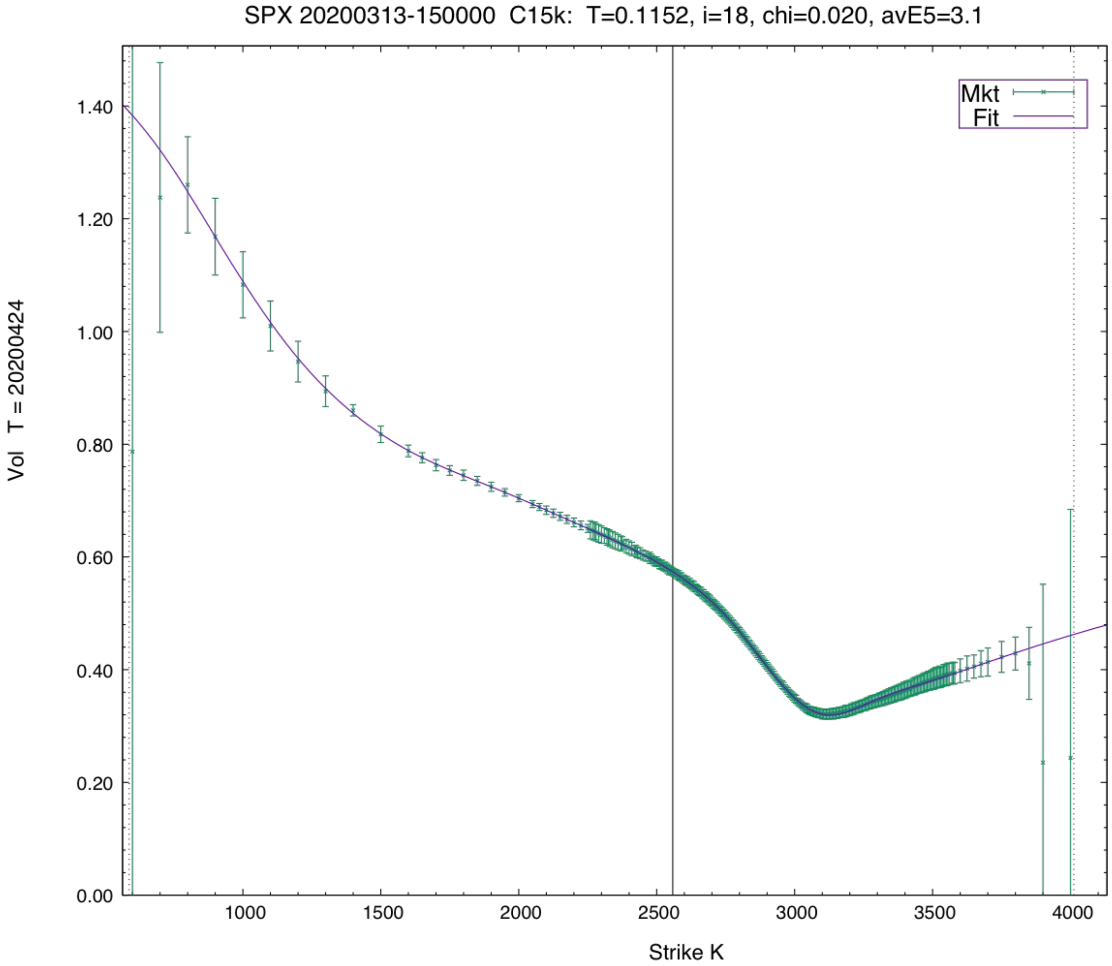
If the fit followed market in put wing more closely there would be fly arb…



SPX 2020-03-13 15:00

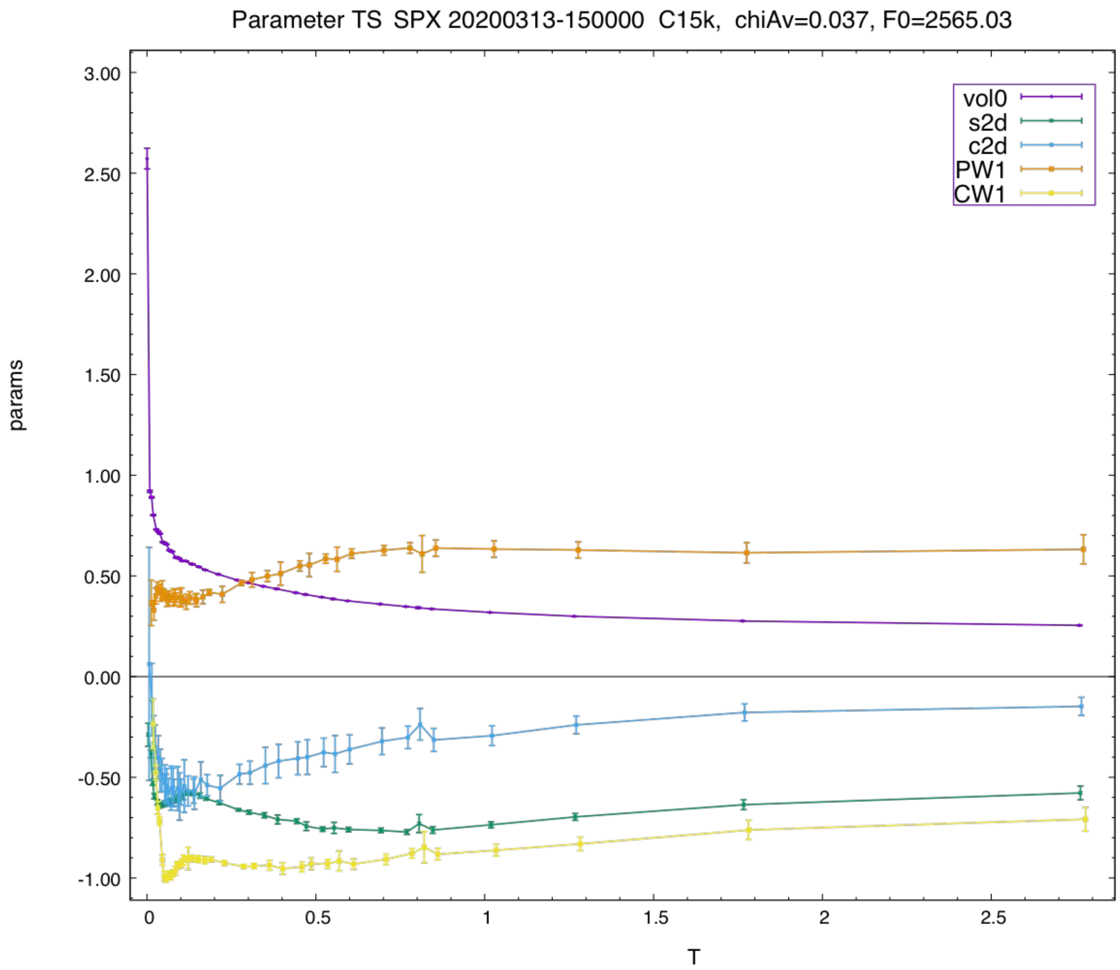
C15K, T = 6w, in NS-space

Very compressed CW, very sharp knee…



SPX 2020-03-13 15:00

C15K, T = 6w, in K-space



SPX 2020-03-13 15:00

C15K Param Term-Structure during the coronavirus crash

First 5 params

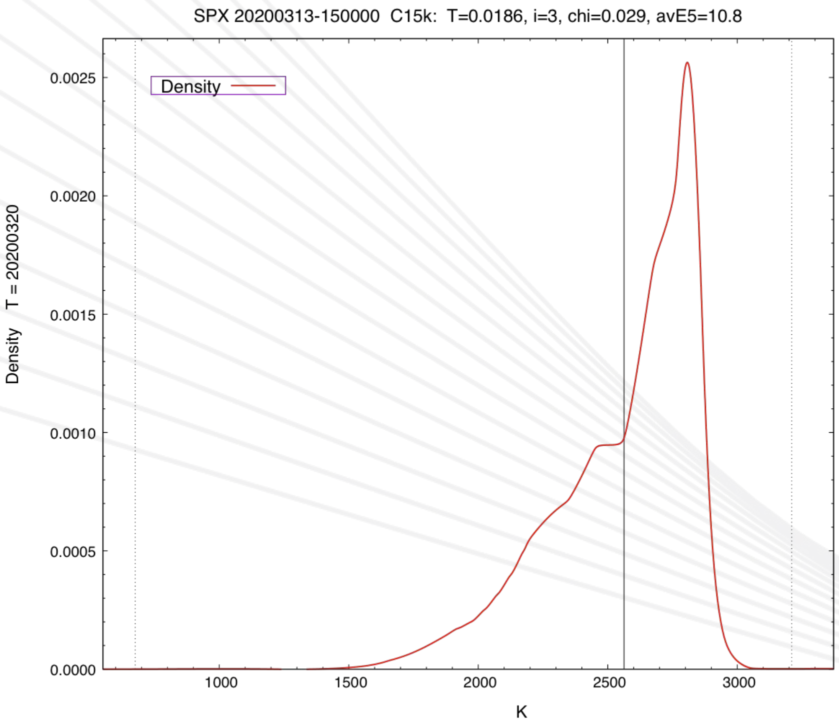
- Unprecedented c2 < 0 for ALL terms
- Super-steep near call wing: **CW1**

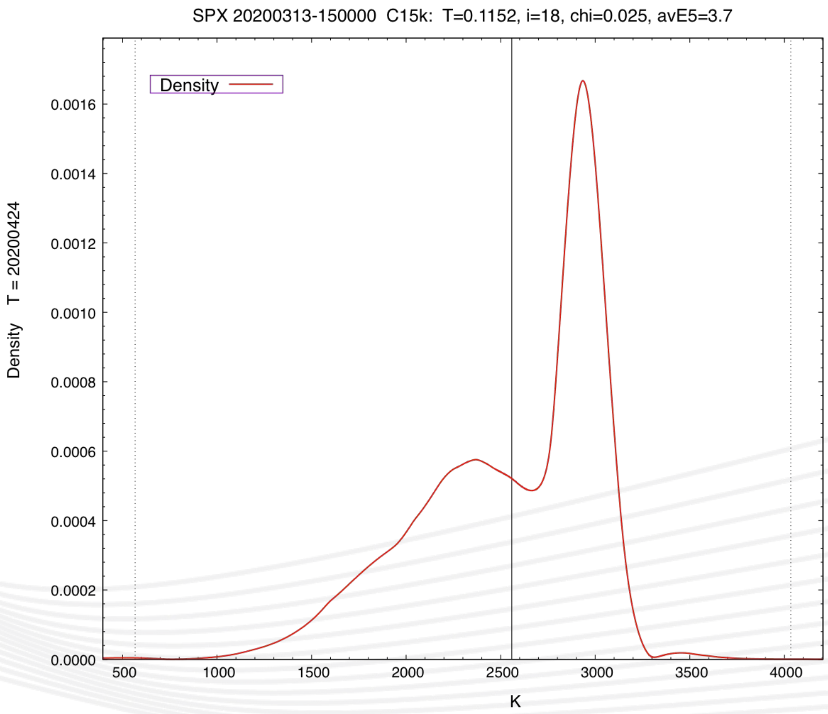
What do the funky shape curves mean?

- They correspond to specific expectations about the underlier evolution.
  - E.g. that SPX can’t go up by more than 17% over one week, but can easily drop by 30%.

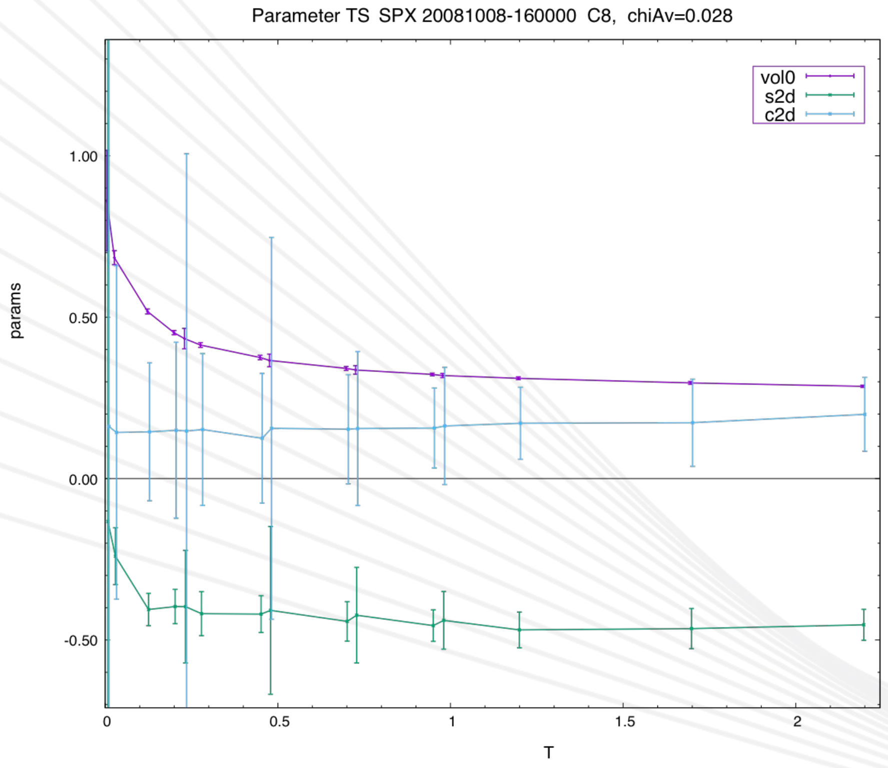
- These expectations are a lot more specific and sophisticated than e.g. during the GFC in 2008.

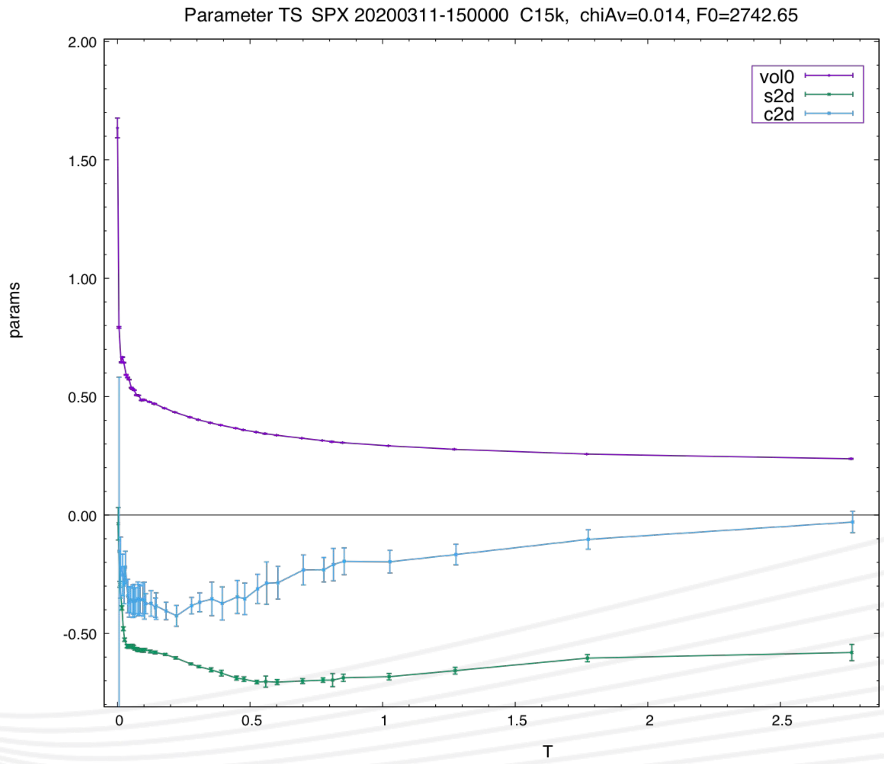
SPX 2020-03-13: Implied densities over 1w and 6w horizons





Parameter TS: 2008 versus 2020

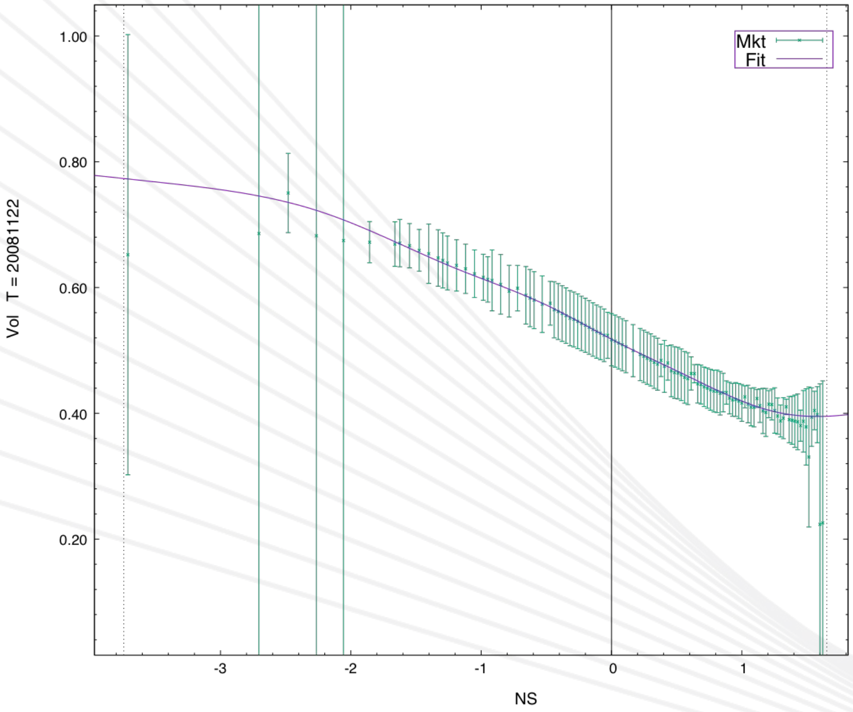




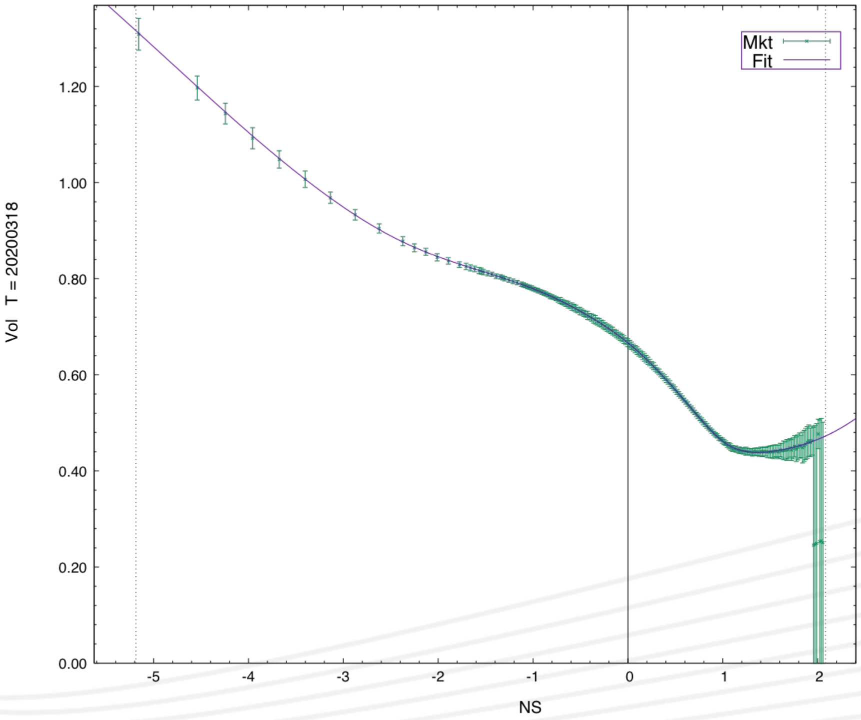
Vol Skews: 2008 versus 2020

VOLA DYNAMICS
Analytics for Options Trading

SPX 20081008-160000 C8: T=0.1227, i=2, chi=0.027, avE5=8.3

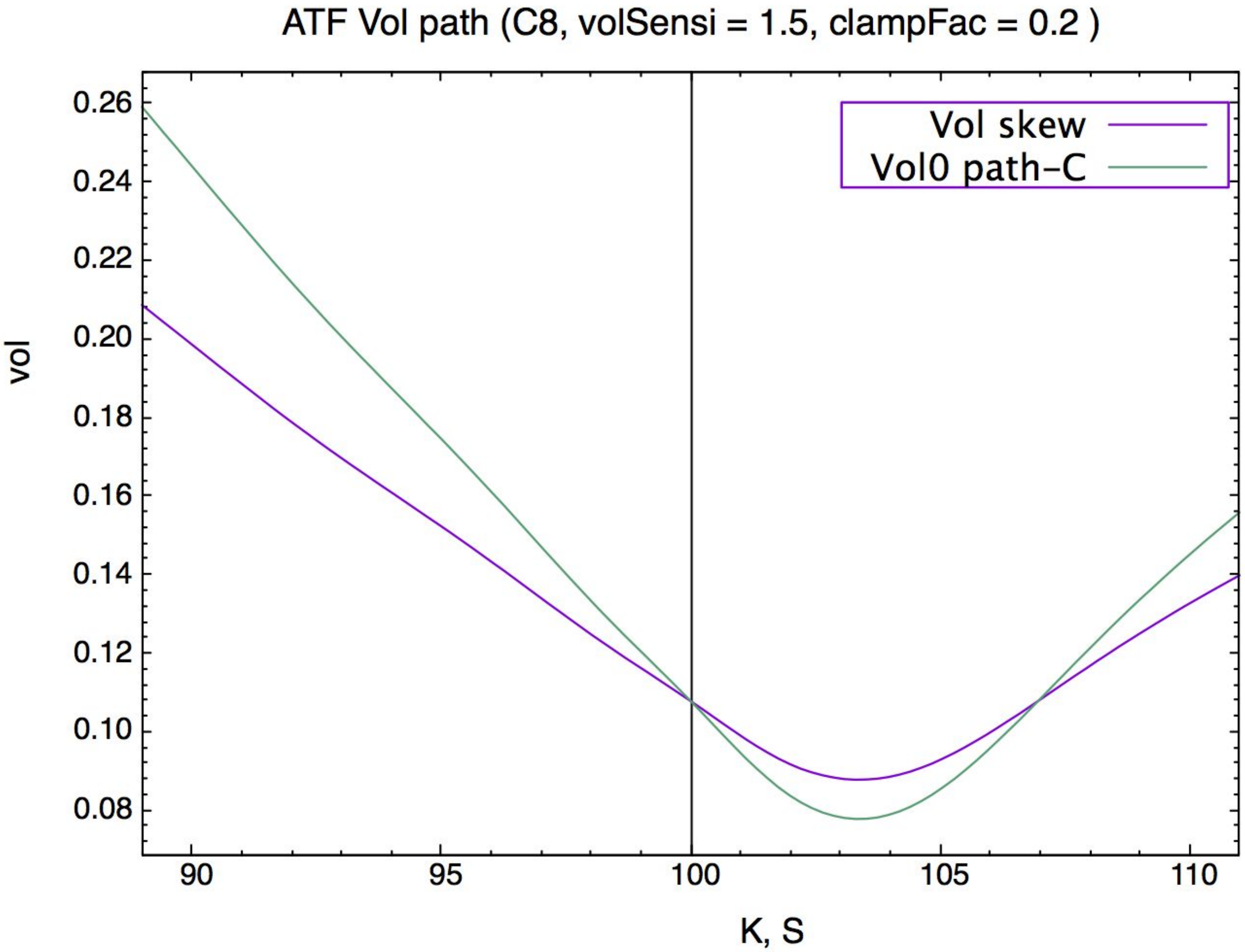


SPX 20200311-150000 C15k: T=0.0193, i=3, chi=0.019, avE5=0.7



What's new with Spot-Vol Dynamics?

- How do vol surfaces move when the underlier moves?
  - Important for smart deltas, automatic theo updates, realistic scenarios, PnL explain, etc.
- "Sticky-Strike" or "Sticky-Delta" vol dynamics have not held for 15+ years.
  - Even on days when Sticky-Strike holds around ATM, it does not hold in wings!
- Mostly, **shapes** have been **sticky** by NS or Delta, but the ATF vol has moved according to a vol sensitivity, SSR, "super-skew", "vol sensi" etc on a steeper curve than the vol skew itself (ratio of slopes = SSR).
- SSR is between 1 and 2, usually, with a typical value of 1.3 to 1.5.
  - Roughly consistent with rough vol...
  - SSR has some horizon dependence from 1-min to 1-hour to 1-day (it's real...).
- **New in 2020** (and for a few years before...)
  - SSR now often has clear term-structure. Moves around more too.
  - There is evidence for curvature (c2) sensitivity to spot, at least on daily horizons.



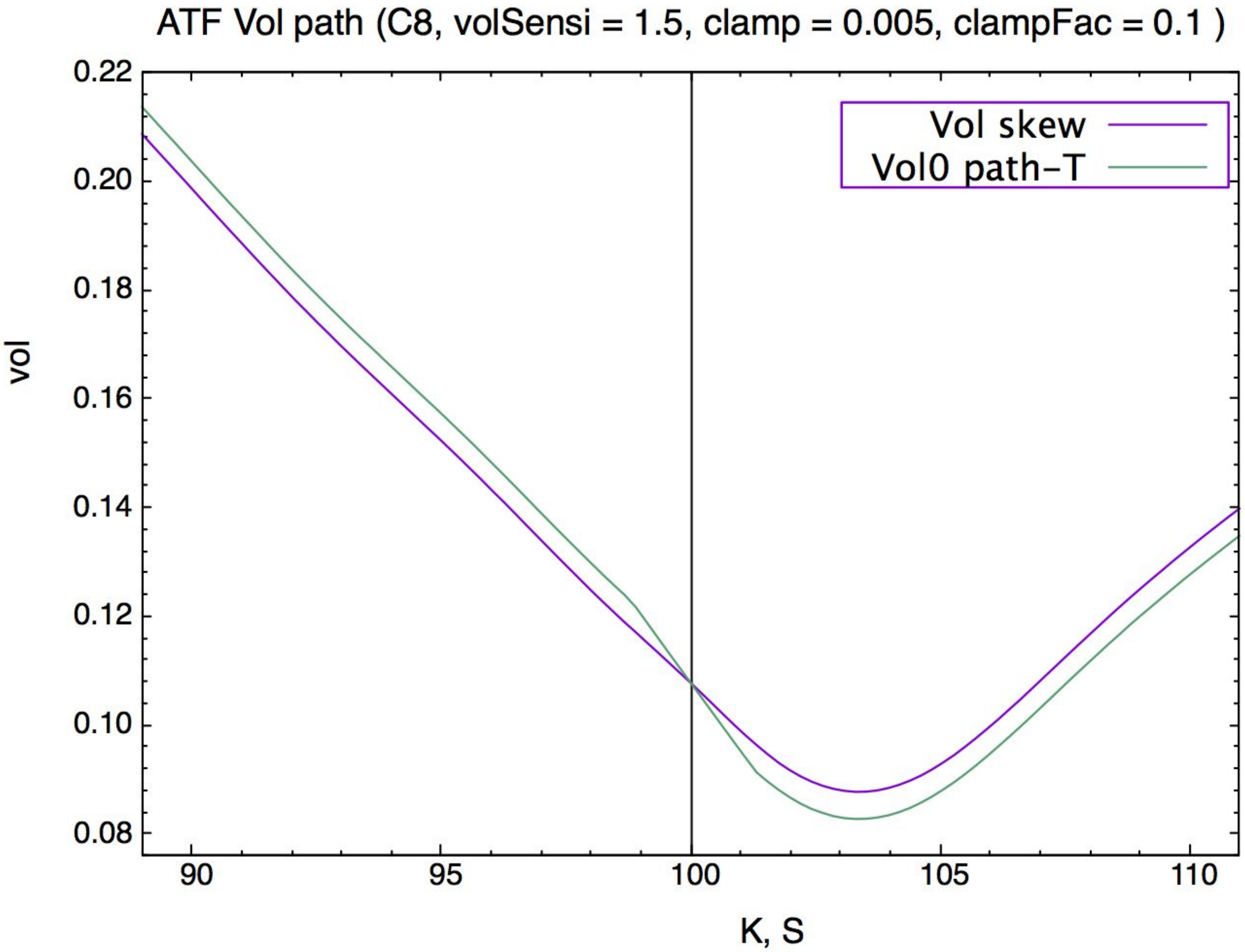
Spot-Vol Dynamics

ATF "vol path"

SSR = 1.5

"Along curve"

No clamps



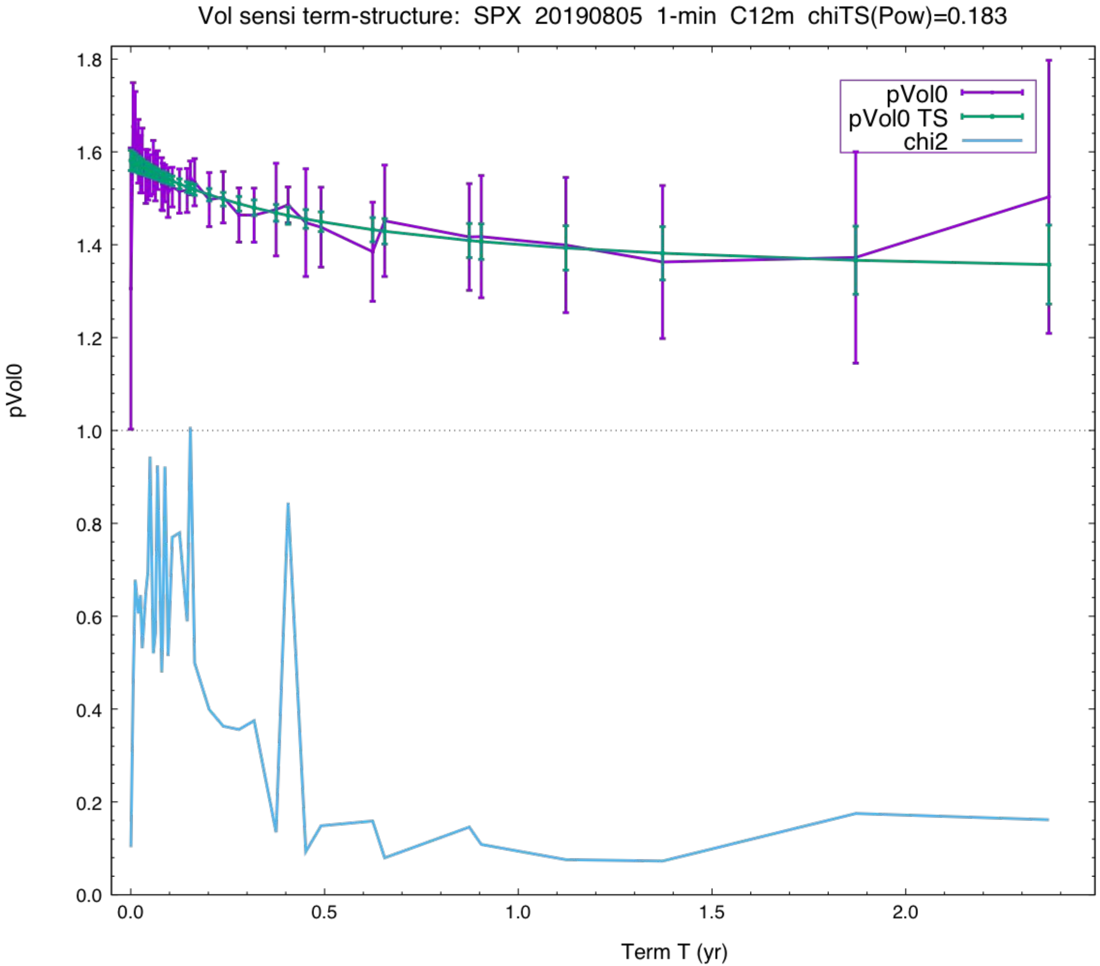
Spot-Vol Dynamics

ATF “vol path”

SSR = 1.5

“Along tangent”

With clamping

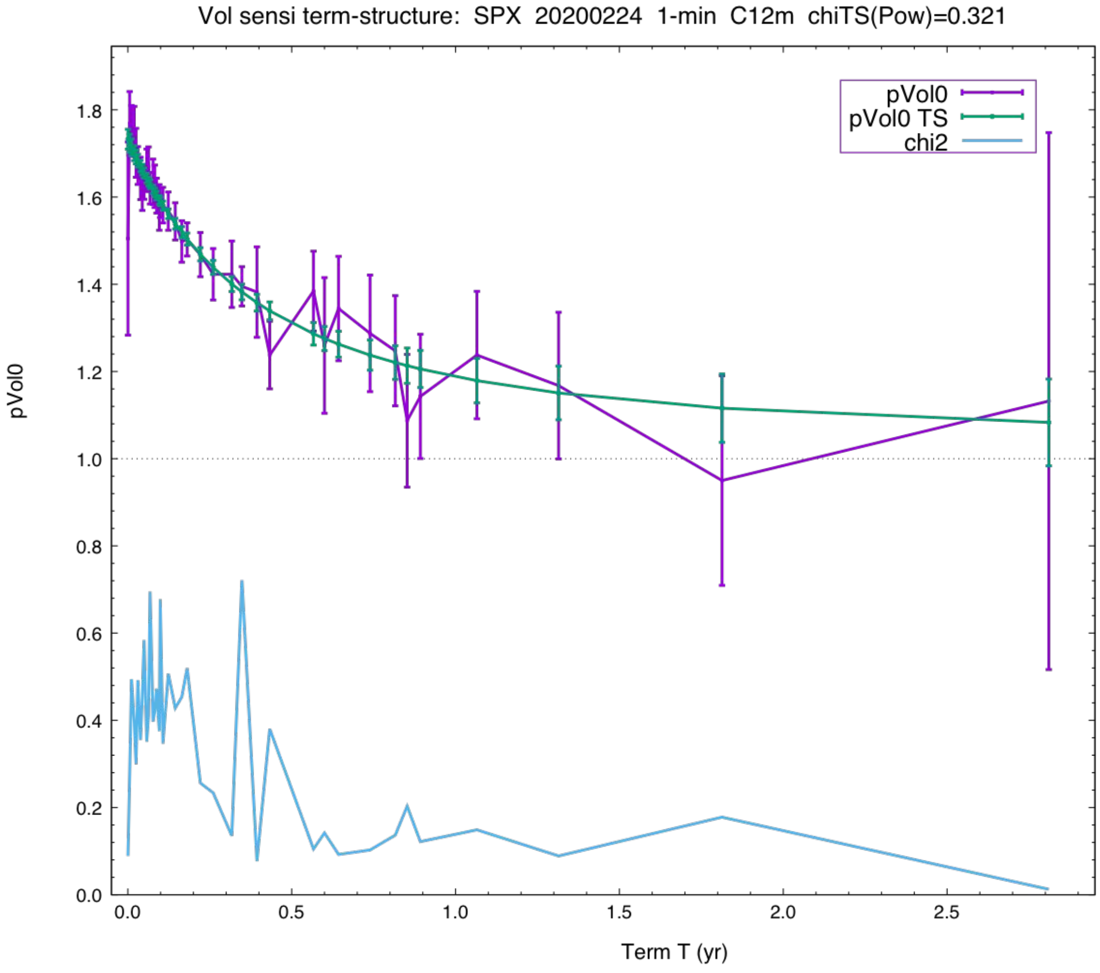


VOLA DYNAMICS
Analytics for Options Trading

SPX 20190805

Vol sensitivity (SSR) term-structure

Parametric fit for robustness on small data sets (can be done intra-day)

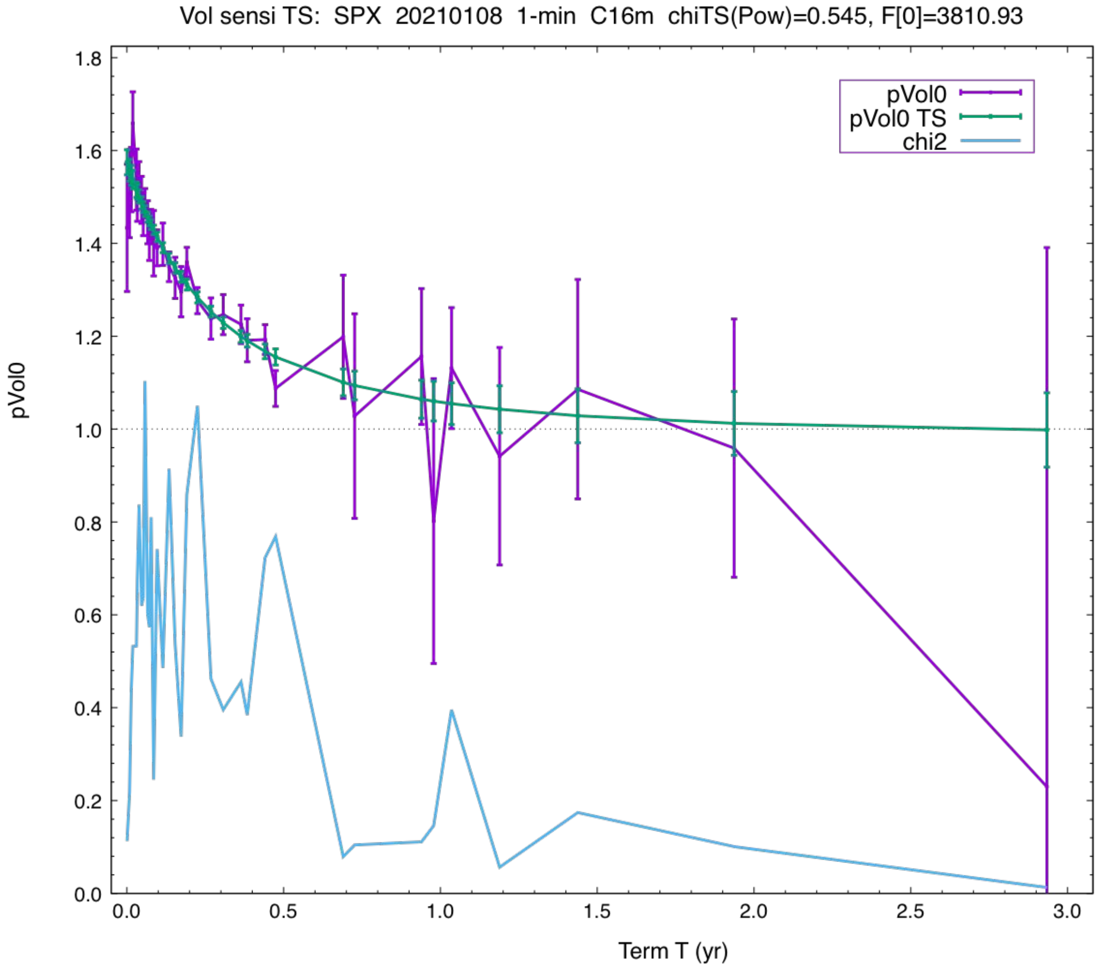


VOLA DYNAMICS
Analytics for Options Trading

SPX 20200224

Vol sensitivity (SSR) term-structure

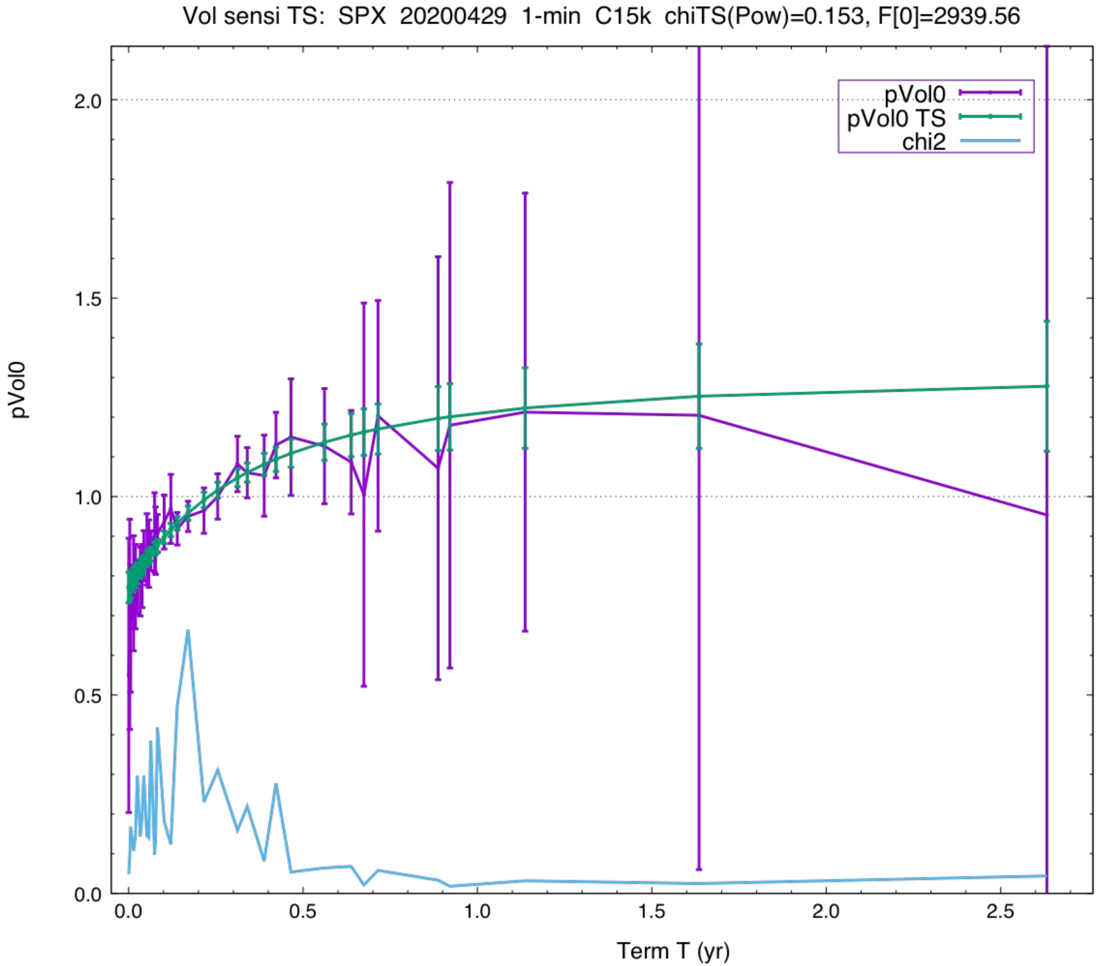
Parametric fit for robustness on small data sets



SPX 20210108

Vol sensitivity (SSR) term-structure

Parametric fit for robustness on small data sets

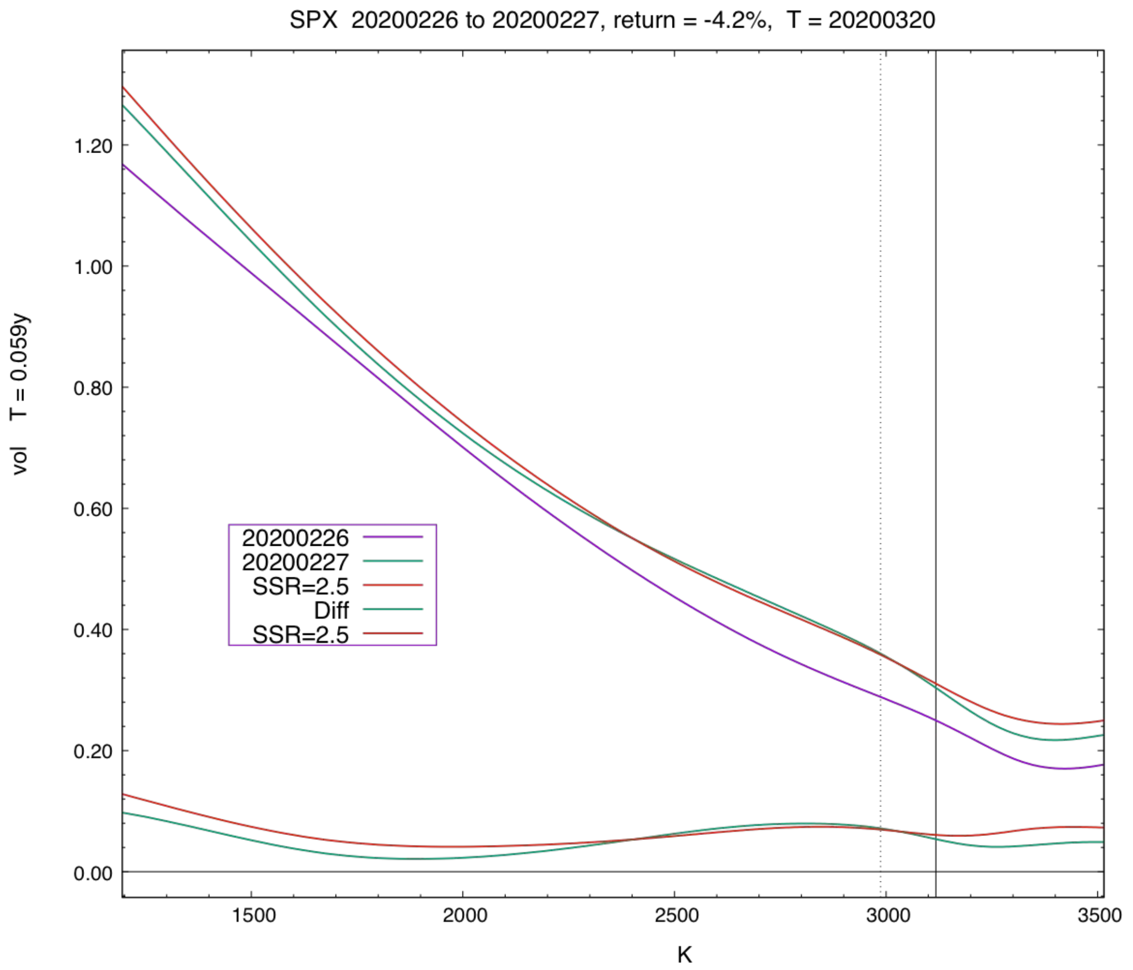


VOLA DYNAMICS
Analytics for Options Trading

SPX 20200429

Vol sensitivity (SSR) term-structure

On up-days can be upward-sloping, and SSR < 1 at least for some terms

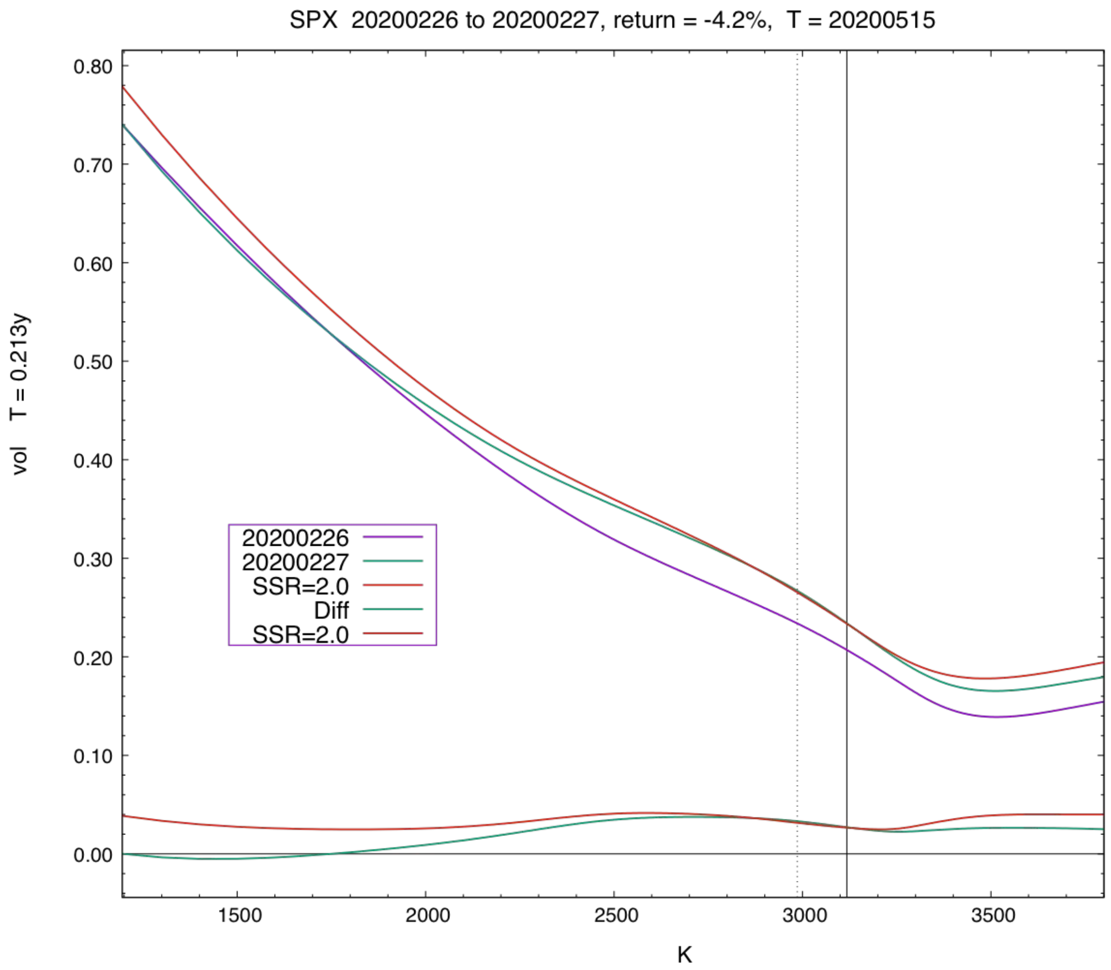


VOLA DYNAMICS
Analytics for Options Trading

SPX 2020-02-26 to 2020-02-27

T = 3w, SSR = 2.5

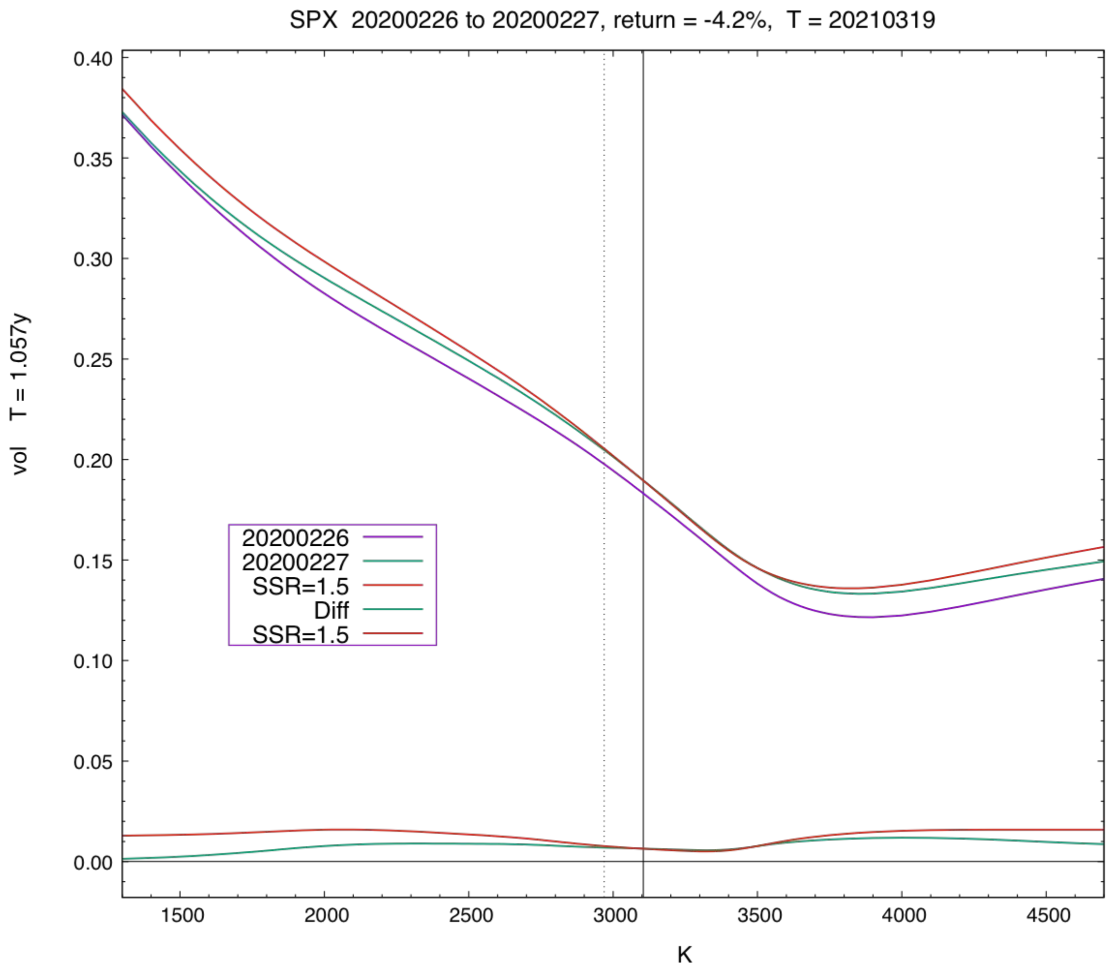
Evidence for c2-spot-sensitivity > 0



SPX 2020-02-26 to 2020-02-27

T = 2.5m, SSR = 2.0

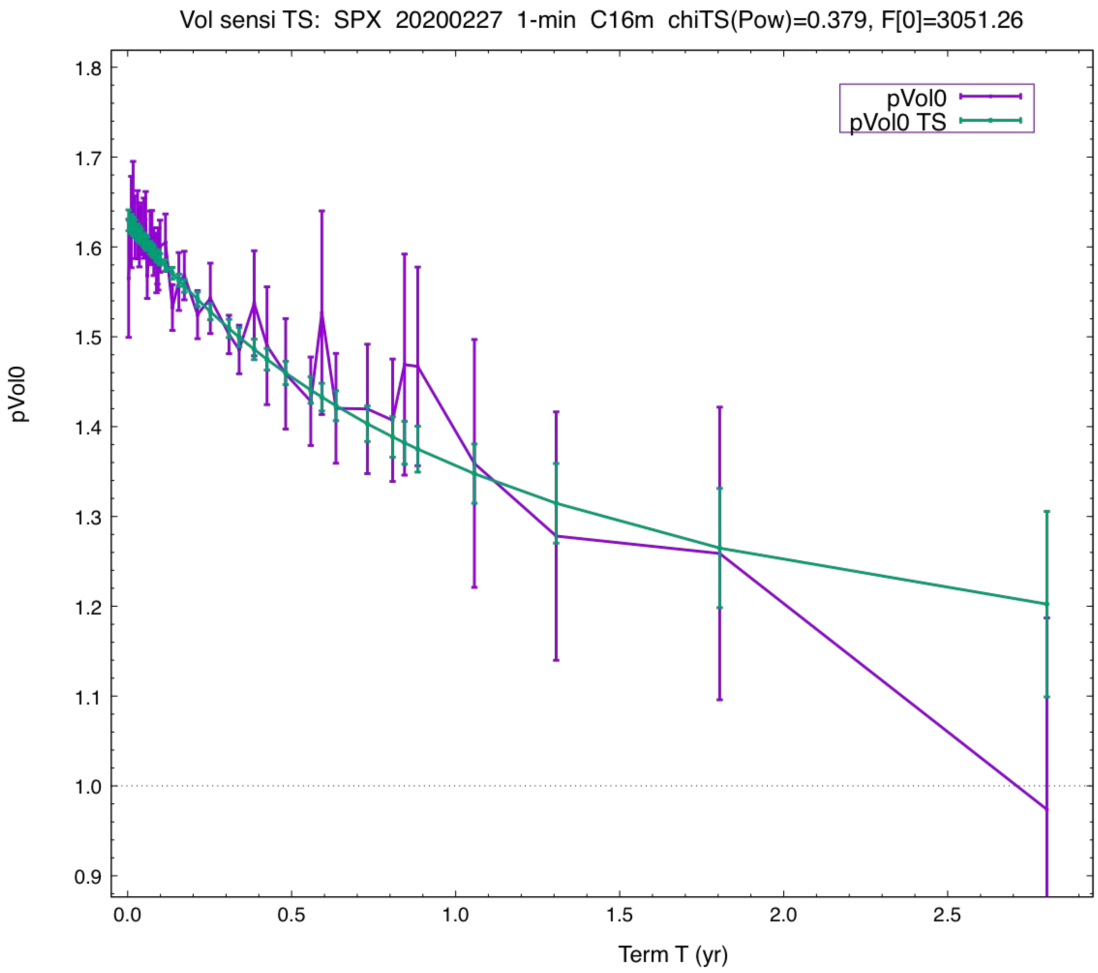
Evidence for c2-spot-sensitivity > 0



SPX 2020-02-26 to 2020-02-27

T = 1y, SSR = 1.5

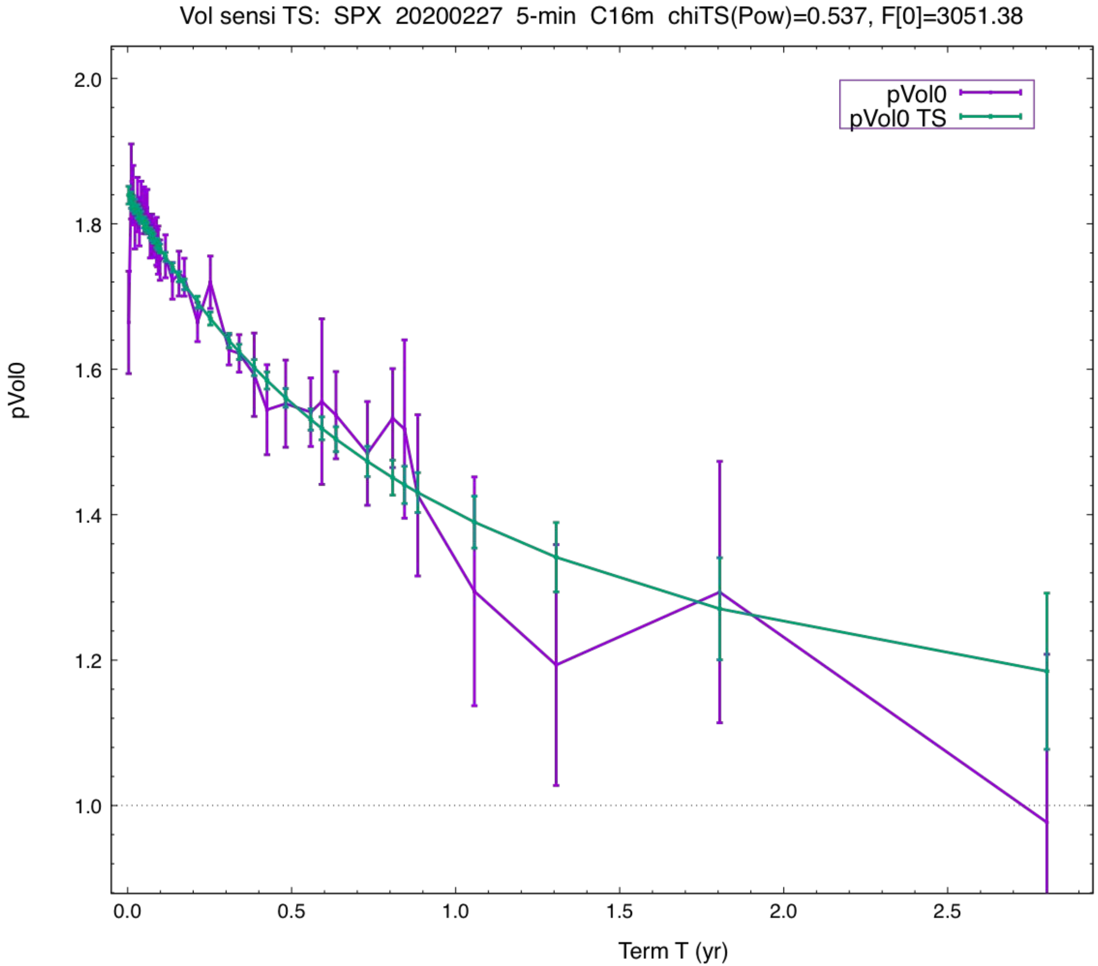
Evidence for c2-spot-sensitivity > 0



SPX 20200227

Vol sensitivity (SSR) term-structure

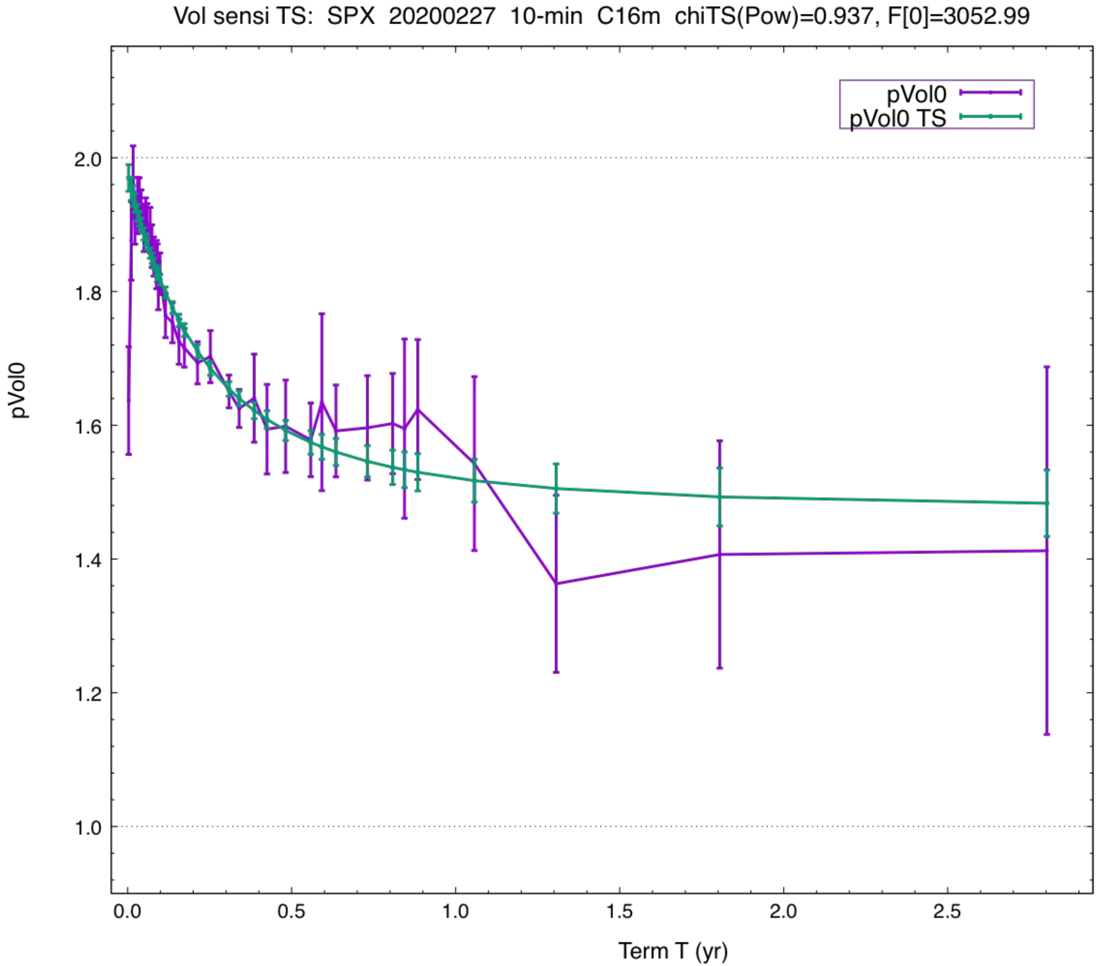
On 1-min horizon



SPX 20200227

Vol sensitivity (SSR) term-structure

On 5-min horizon

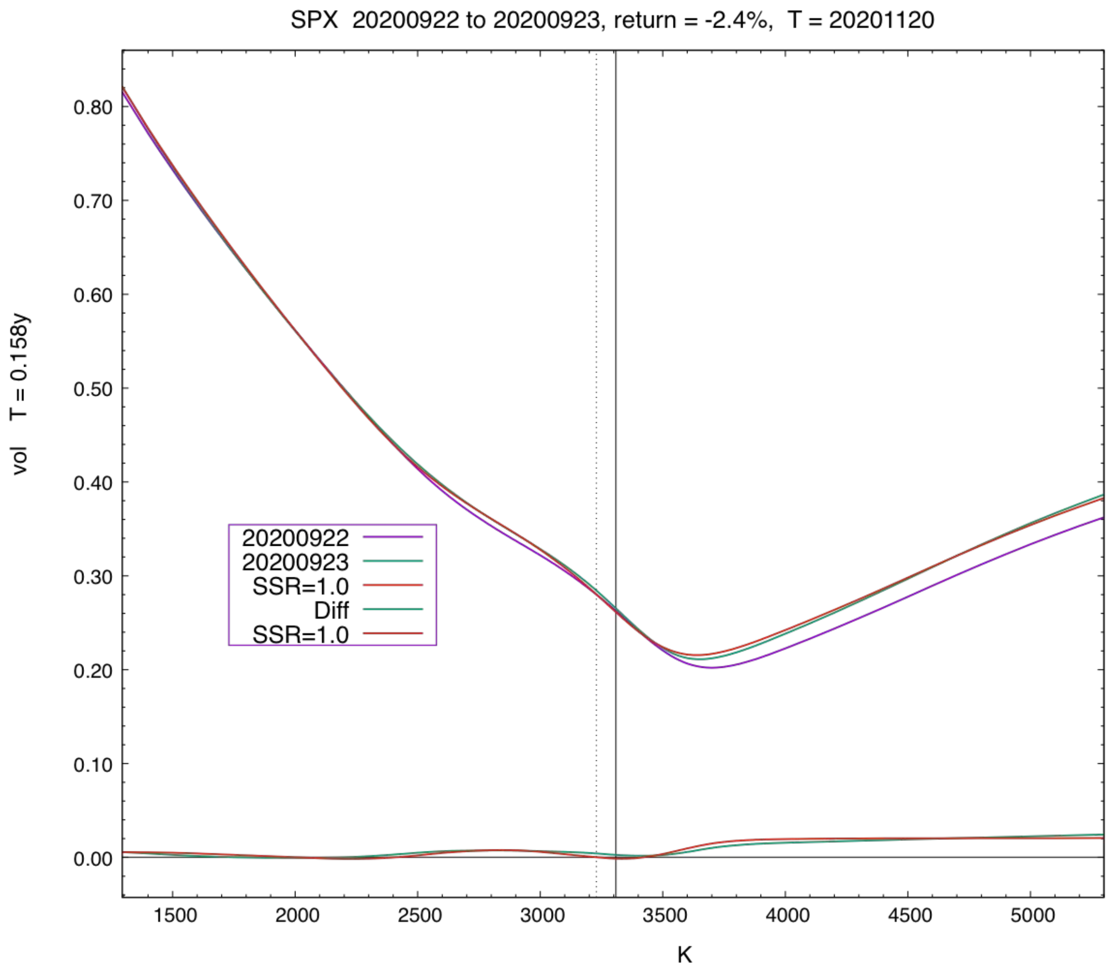


SPX 20200227

Vol sensitivity (SSR) term-structure

On 10-min horizon

One 1-day horizon even larger here,
at least for short terms.



SPX 2020-09-22 to 2020-09-23

Even when SSR = 1 does sticky-strike only hold around ATM, not in the wing(s):

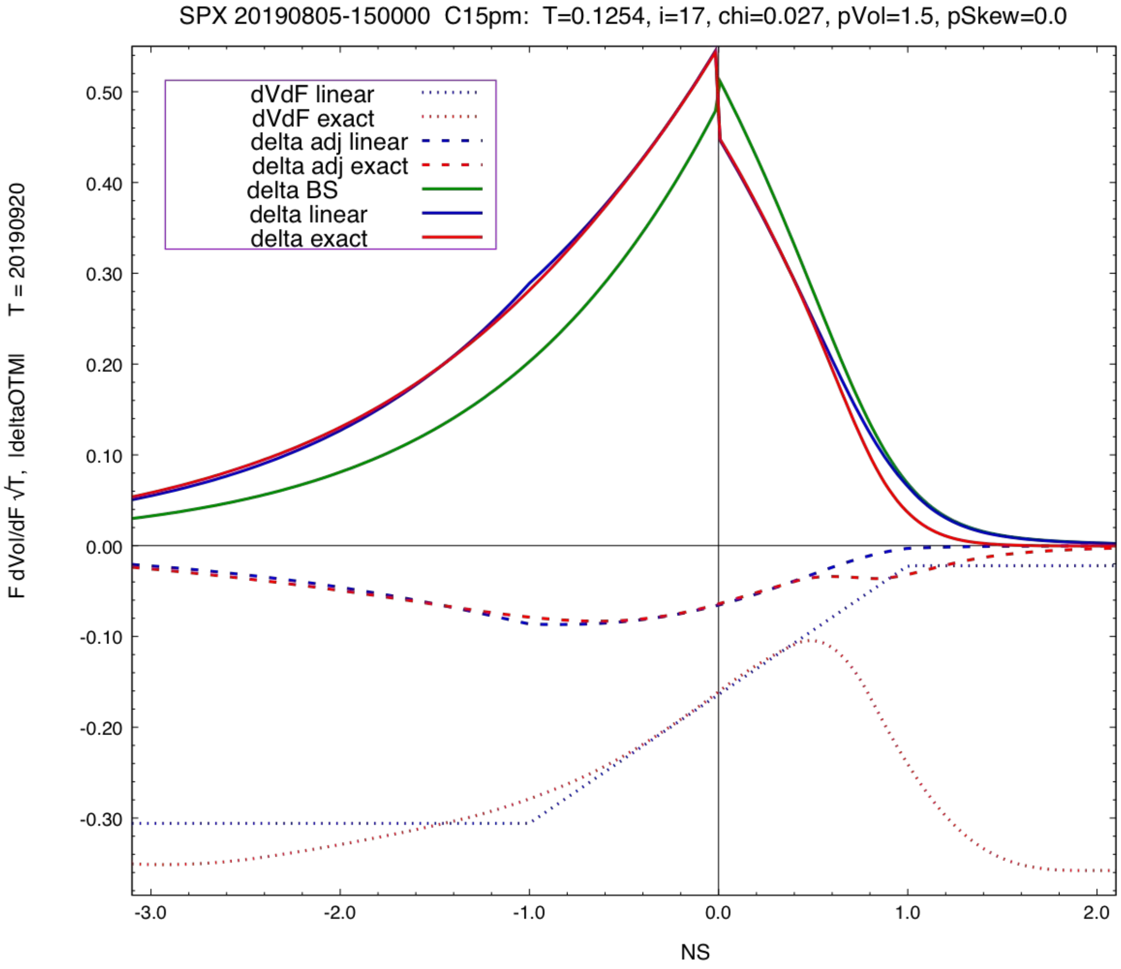
Shapes are sticky-by-NS !!

This down-day comes after a sequence of (minor) down days, and SSR has mean-reverted/reversed to 1…

Spot-Vol Dynamics, Crazy Vol Shapes and Delta

VOLA DYNAMICS
Analytics for Options Trading

- What is the **correct delta of a vanilla option**?
  - Delta (w/r/t F) = DeltaBlack + vega * dVol/dF
- dVdF (:= dVol/dF) and the delta adjustment are very large these days!
- dVdF can be calculated from the spot-vol dynamics.
  - Spot-Vol Dynamics is equivalent to knowing the optimal delta (hedges spot-correlated vol move).
- If shapes are stable just one dimensionless number (SSR) is needed.
- Fixed-strike dynamics, i.e. dVdF, and vol parameter dynamics (aka “vol path” for first parameter) behave qualitatively very differently (as we saw already)!
  - Only simple (robust) linear regressions are needed for parameter dynamics.
- For details, see our LinkedIn post.... Or briefly below...



VOLA DYNAMICS
Analytics for Options Trading

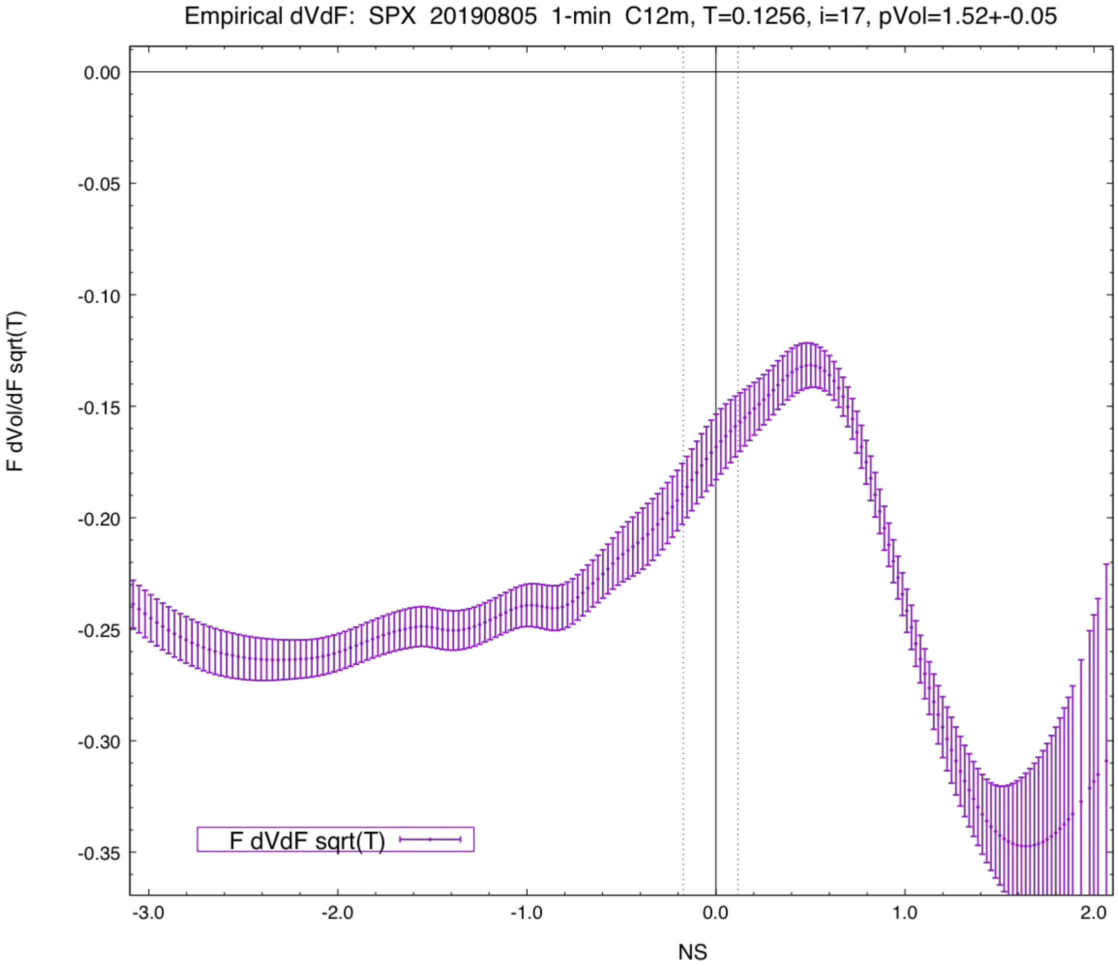
SPX 20190805 T=0.13y M2

- Normalized dVol/dF
- Delta adjustments
- Final deltas

These dVdF (etc) curves are extremely stable across time, curve-type, algo details, etc.

Note: Fixed strike dVdF is plotted as a function of NS (using average F,T,vol0 over day).

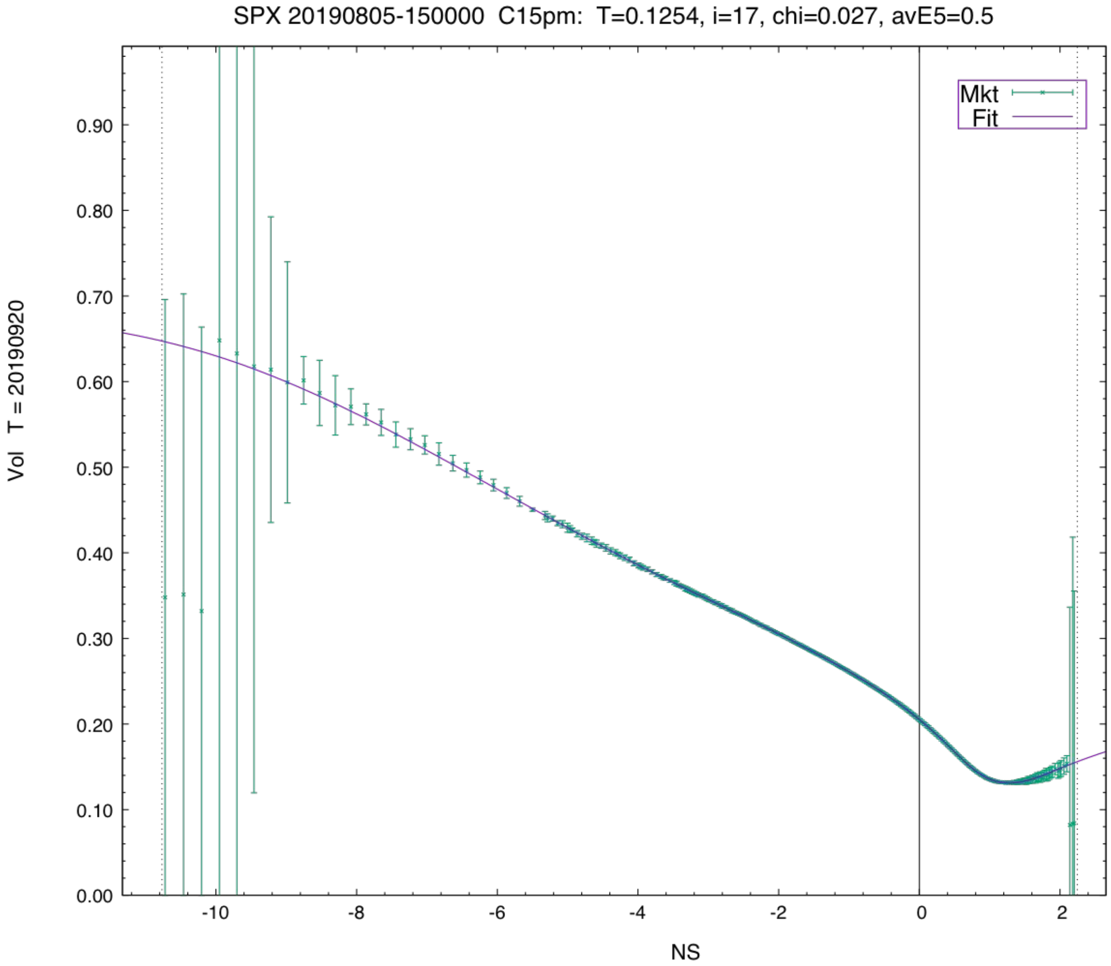
Some firms use constant or linear approx for dVdF(K): Linear approx is fine in put wing, bad in call wing



VOLA DYNAMICS
Analytics for Options Trading

SPX 20190805 T=0.13y M2

- Empirical regression of dvol vs dF for each strike, using 1-min data from 10:00 - 16:00
- Is consistent with SSR=1.5 and sticky-NS-shape dynamics over quite wide range!



VOLA DYNAMICS
Analytics for Options Trading

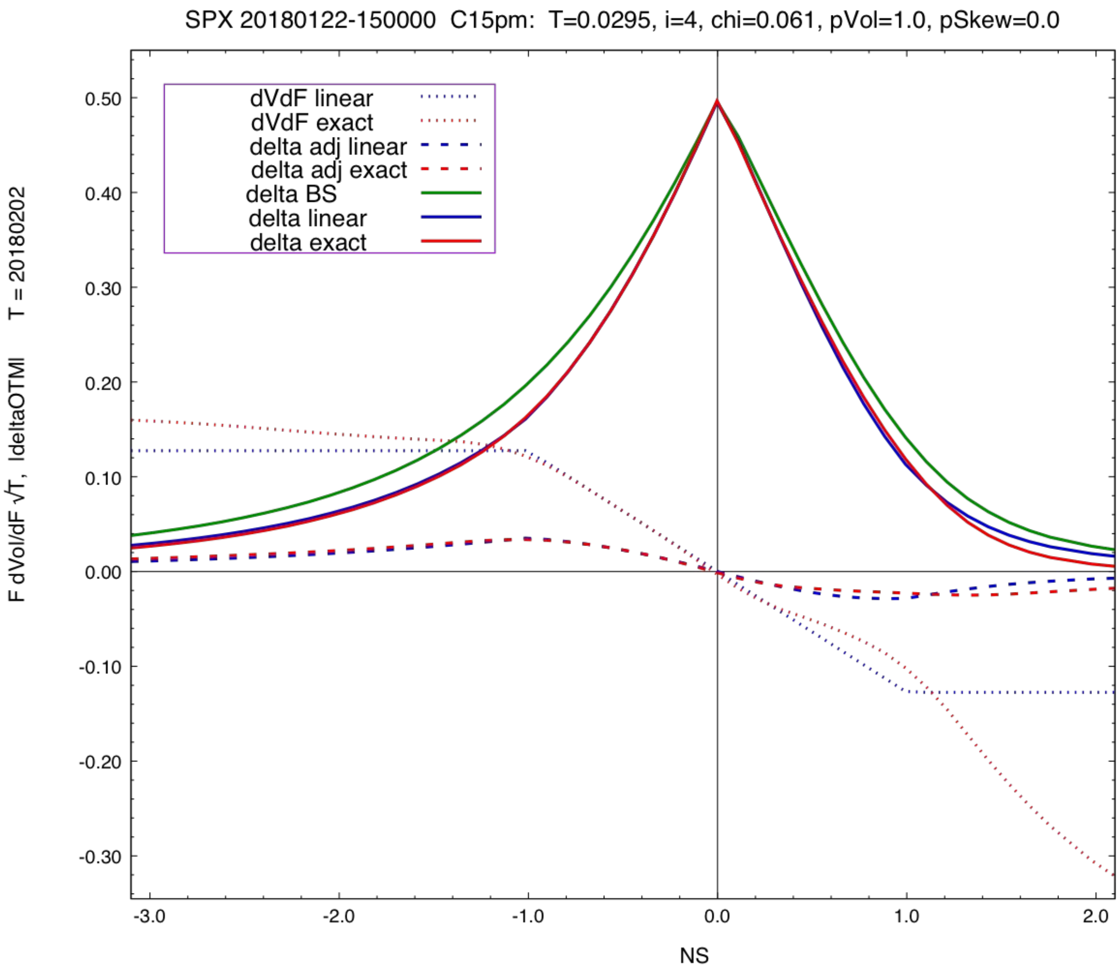
SPX 20190805 T=0.13y M2

Super stable fit….

With steep “knee” at NS = +1.0

ATM parabola does not describe knee at all -- ATM curvature is negative!!

Explains break-down of linear approximation

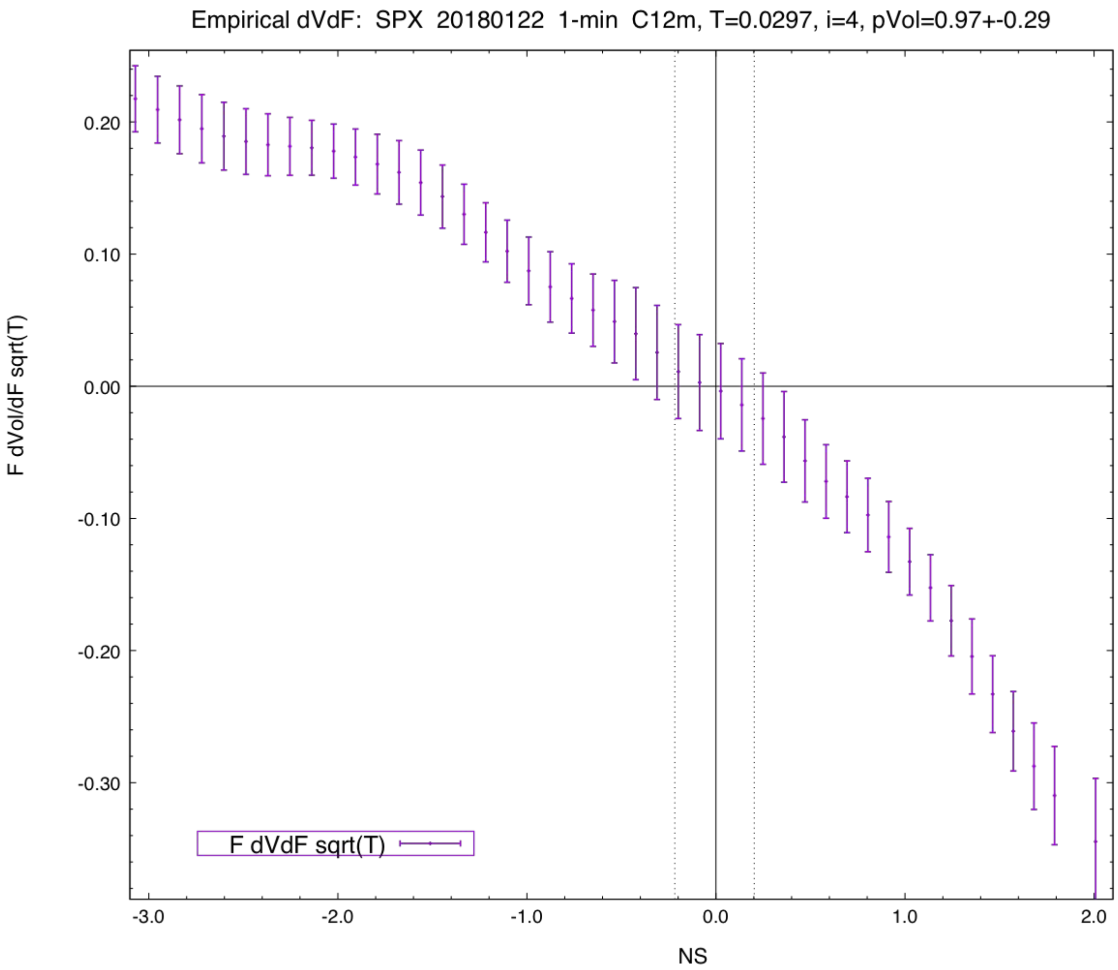


VOLA DYNAMICS
Analytics for Options Trading

SPX 20180122 T=0.06y M1

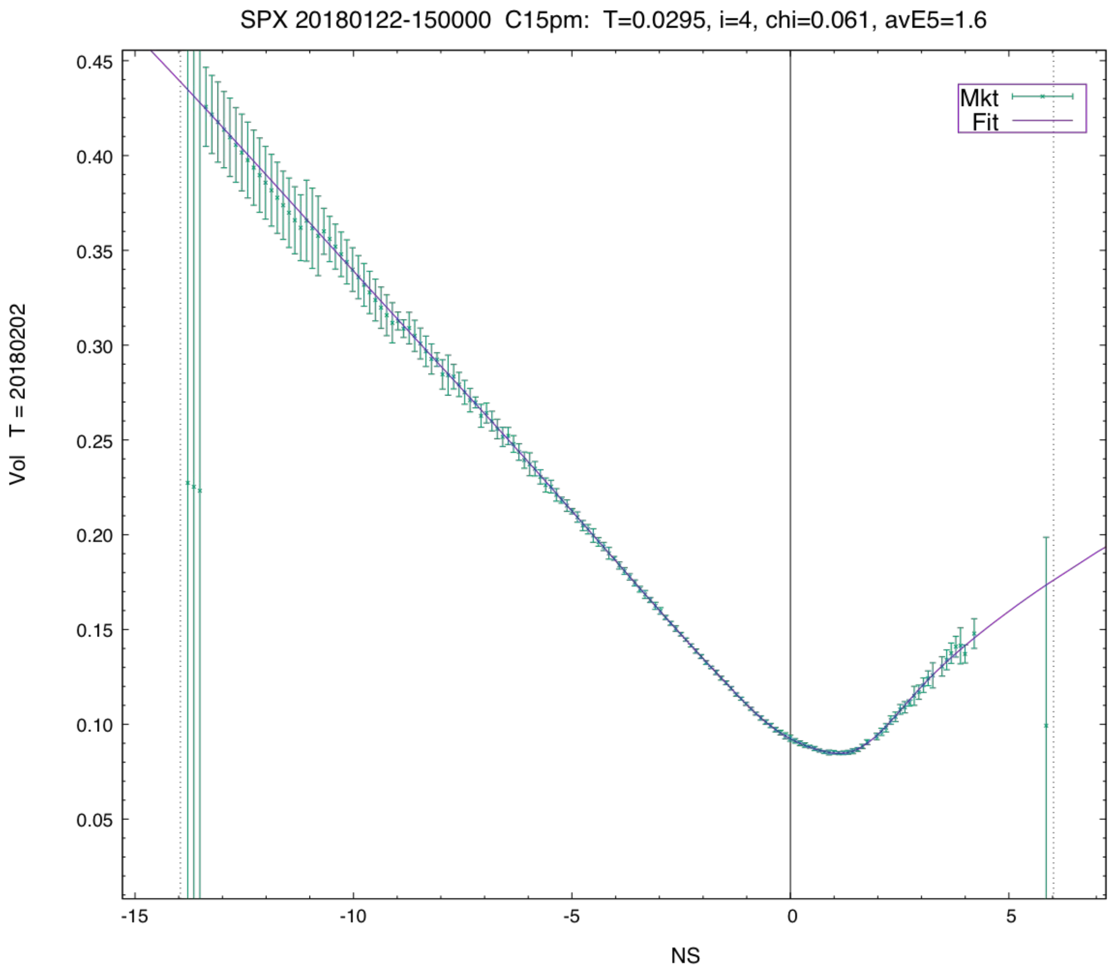
- Normalized dVol/dF
- Delta adjustments
- Final deltas

Very different from 20190805, but still described well by just one number, SSR=1.0, and the precise vol curve fit…



SPX 20180122 T=0.06y

- Empirical regression of dvol vs dF for each strike, using 1-min data from 10:00 - 16:00
- Is consistent with pVol=1.0 and sticky-NS-shape dynamics over quite wide range!
- And yes, **dVdF can really be > 0** in put wing, even for indices.



VOLA DYNAMICS
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SPX 20180122 T=0.06y

Super stable fit….

With steep “knee” at NS = +1.0

Here ATM parabola is not horrible in describing minimum, until NS=1.2 or so.

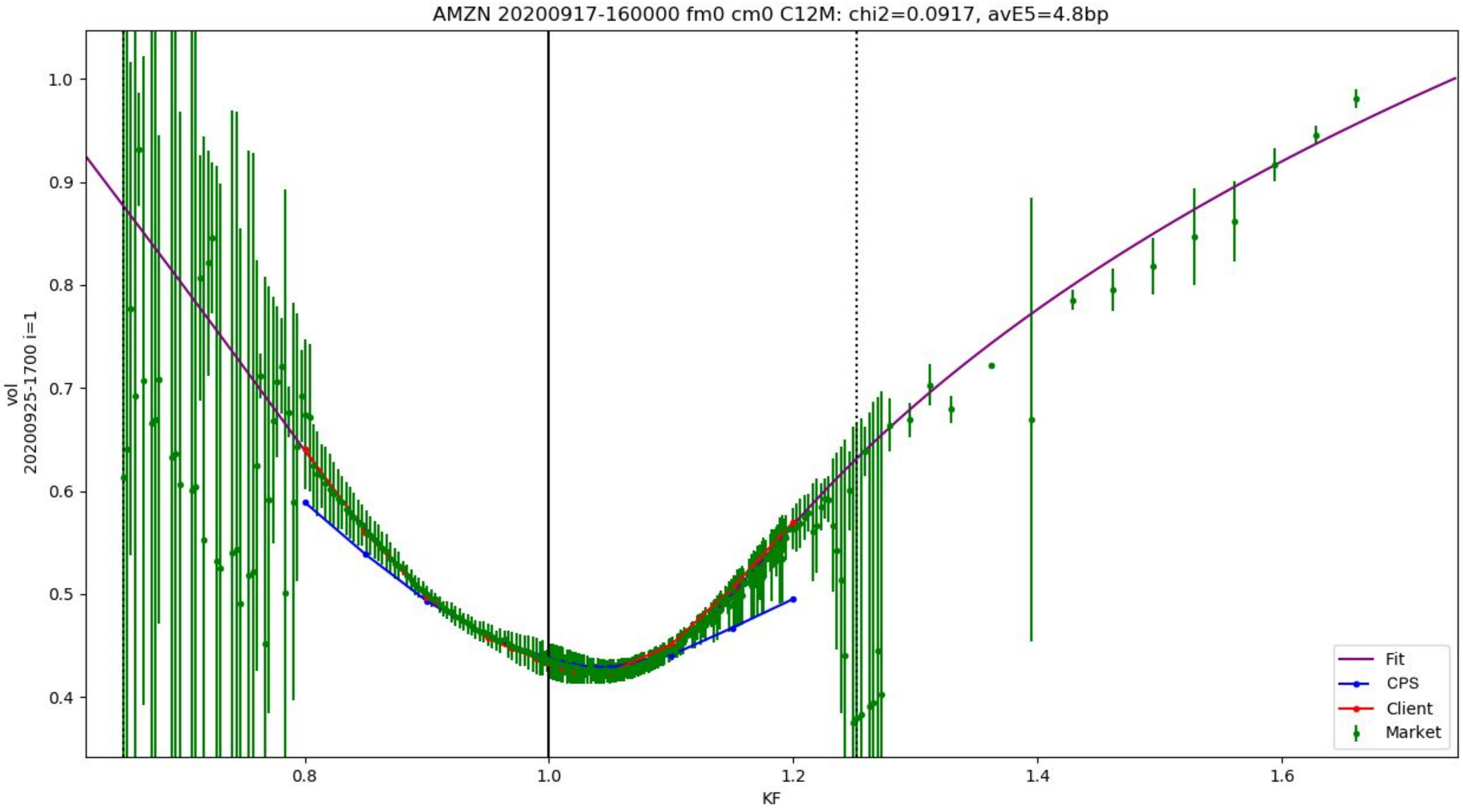
Questions arising for a bank desk when using sub-par curves

VOLA DYNAMICS
Analytics for Options Trading

- Model Control/Valuation & Regulators would like the same surface/theos to be used across Flow, Exotics and OMM desks for a given name (one would hope...)
- How much time is spent massaging curves/surfaces?
  - A lot, it seems. Even then: A top tier bank had no SPX vol surface for 2 days in March...
- If the curves/surfaces are not flexible enough to match the market:
  - Actual "best" fit depends on weights put on different strike ranges. Not stable, will sometimes jump...
  - How to (bias-) correct? Different recipes for each product...
  - Even for var swaps: Is infinite-strip fair vol accurate? No. Is basis stable? Unlikely...
- Structured Products: Simple curves do not even match longer term market...
  - How to hedge with vanillas? How to test that using simple curves for longer-dated SP does not lead to significant model error in valuation and risk? What happens once products are close to expiry?
- How important is proper spot-vol dynamics for exotics/SP deltas, vegas, etc?
- Can one trust a consensus pricing service for options valuation?

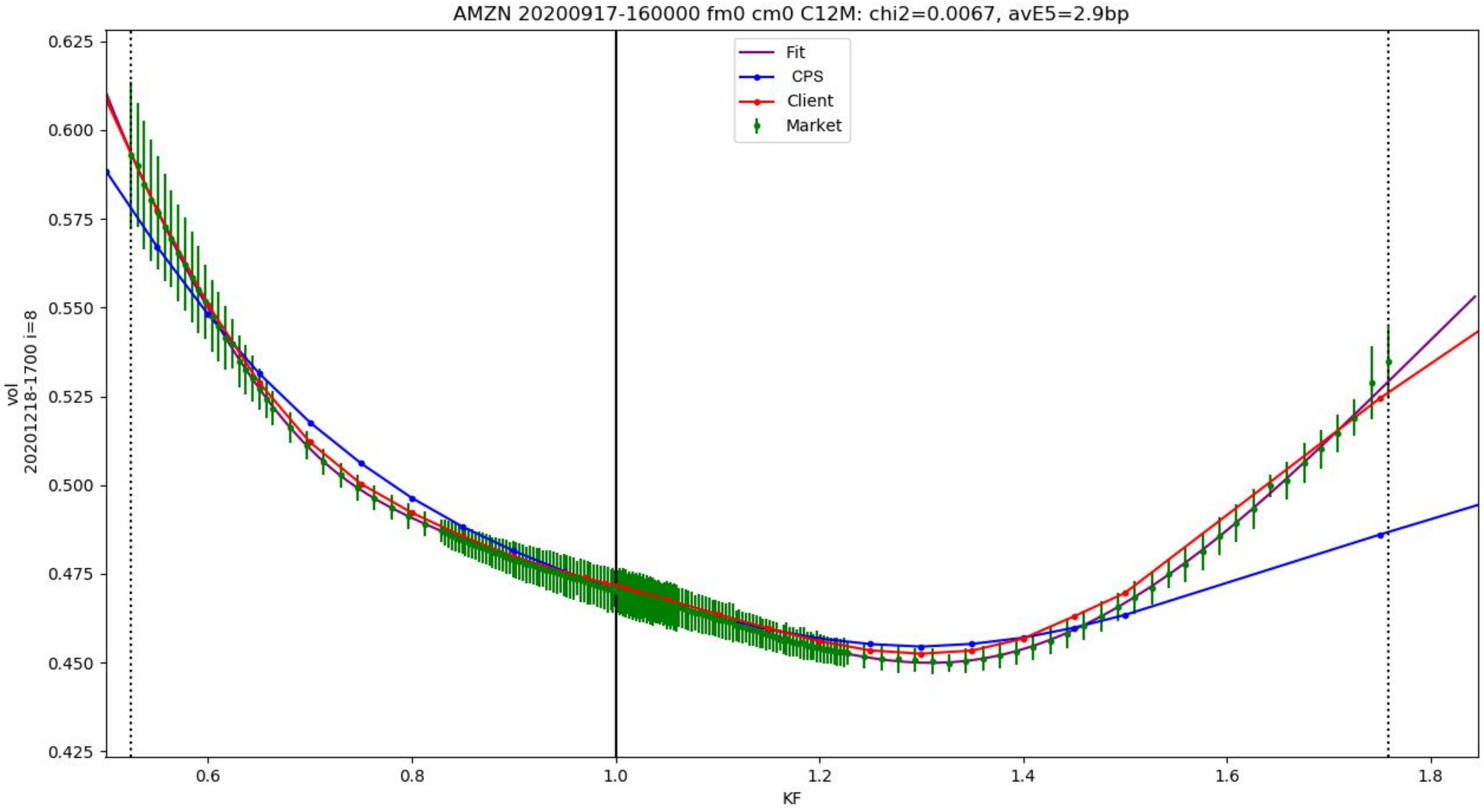
Consensus Pricing Service versus the listed AMZN market

AMZN 2020-09-17, T = 1w



Consensus Pricing Service versus the listed AMZN market

AMZN 2020-09-17, T = 3m



Questions?

Do you need tools for options and derivatives trading, in automated/electronic or any other fashion?

- Sophisticated prop shops, hedge funds, and banks rely on the Vola Dynamics quant library.
- See VolaDynamics.com, email info@VolaDynamics.com