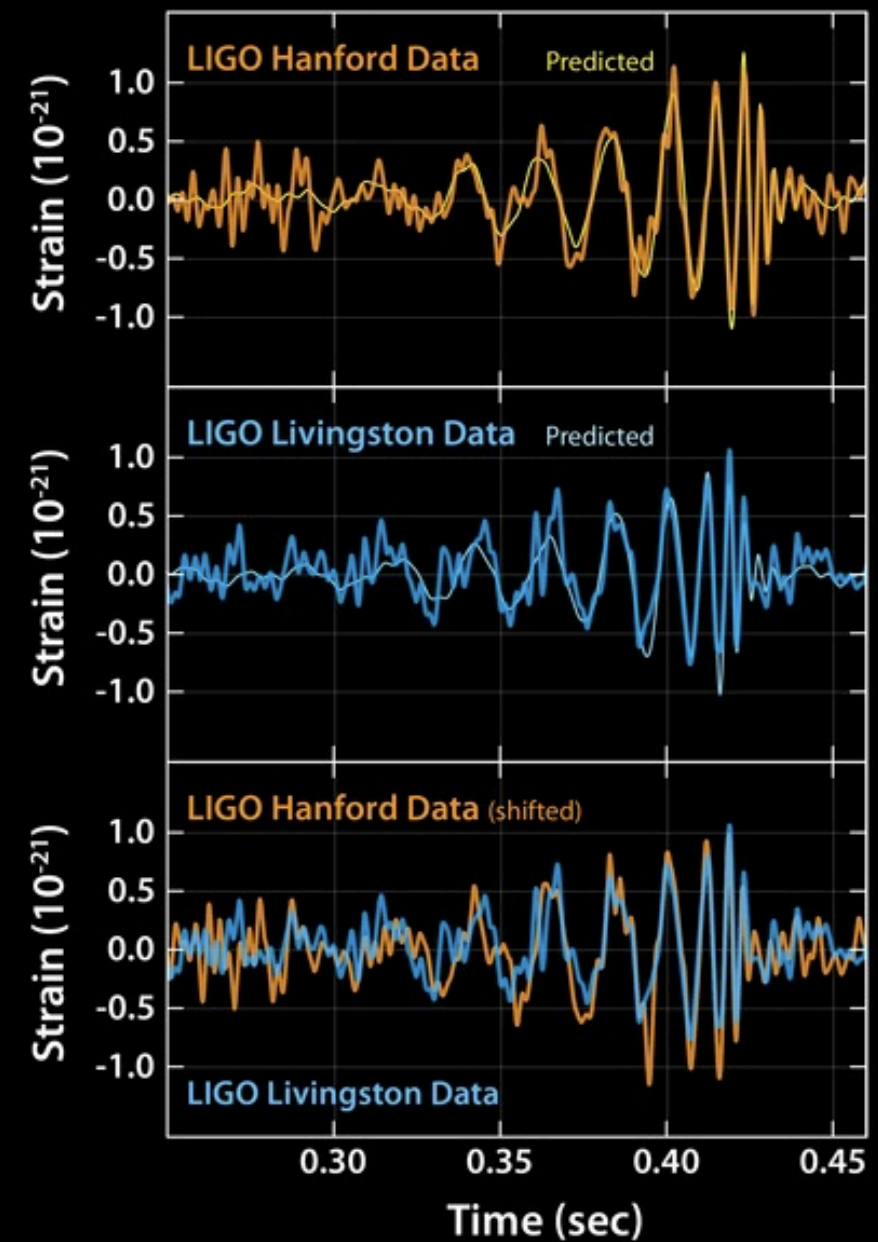
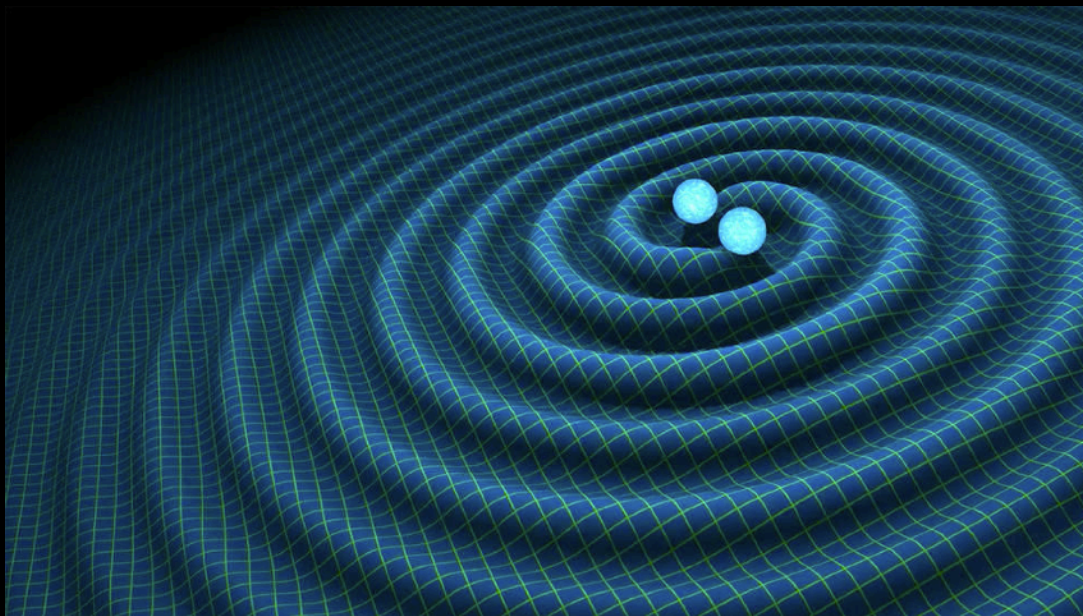
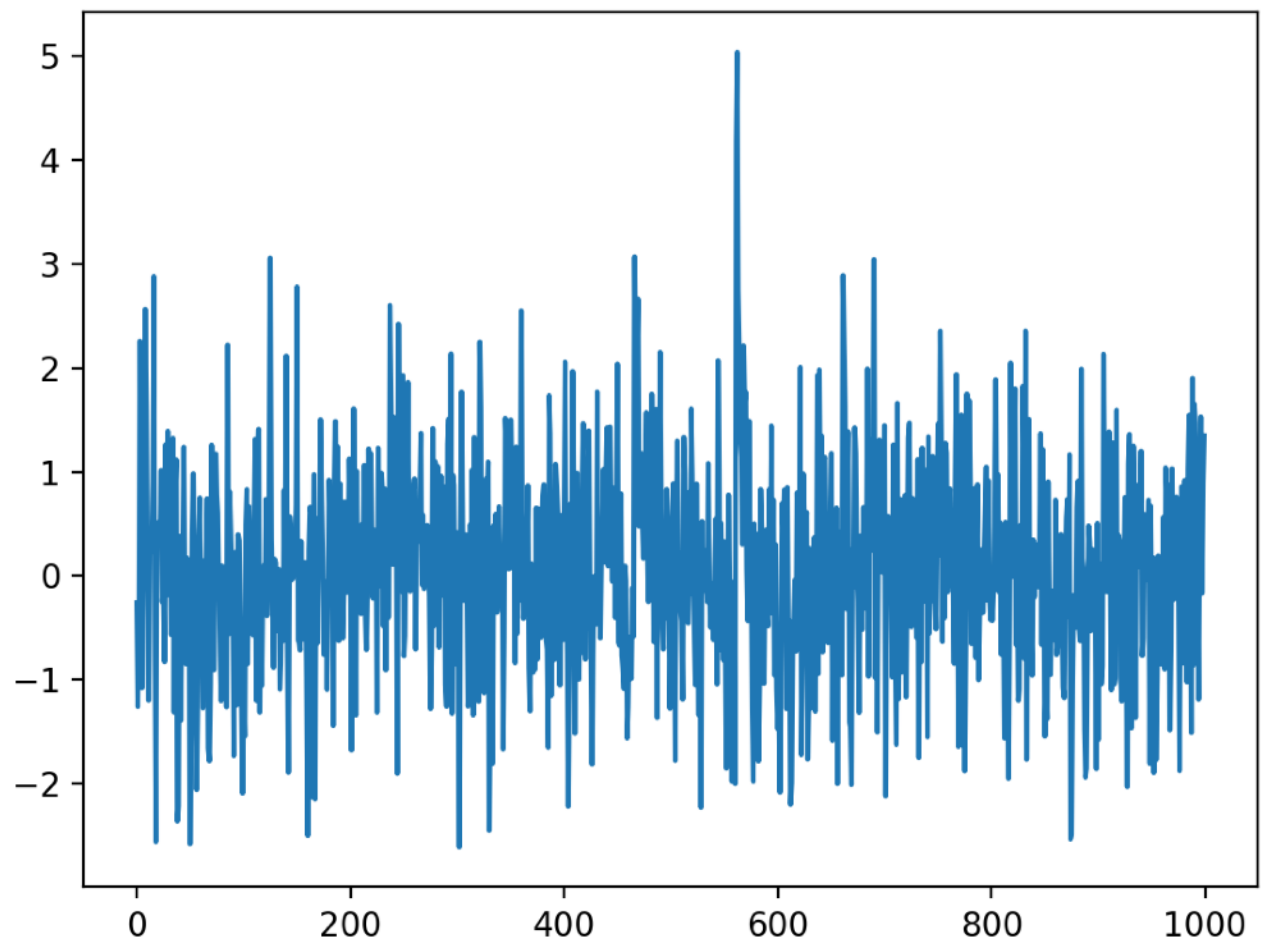


Matched Filters/Ligo



Searching for Signals

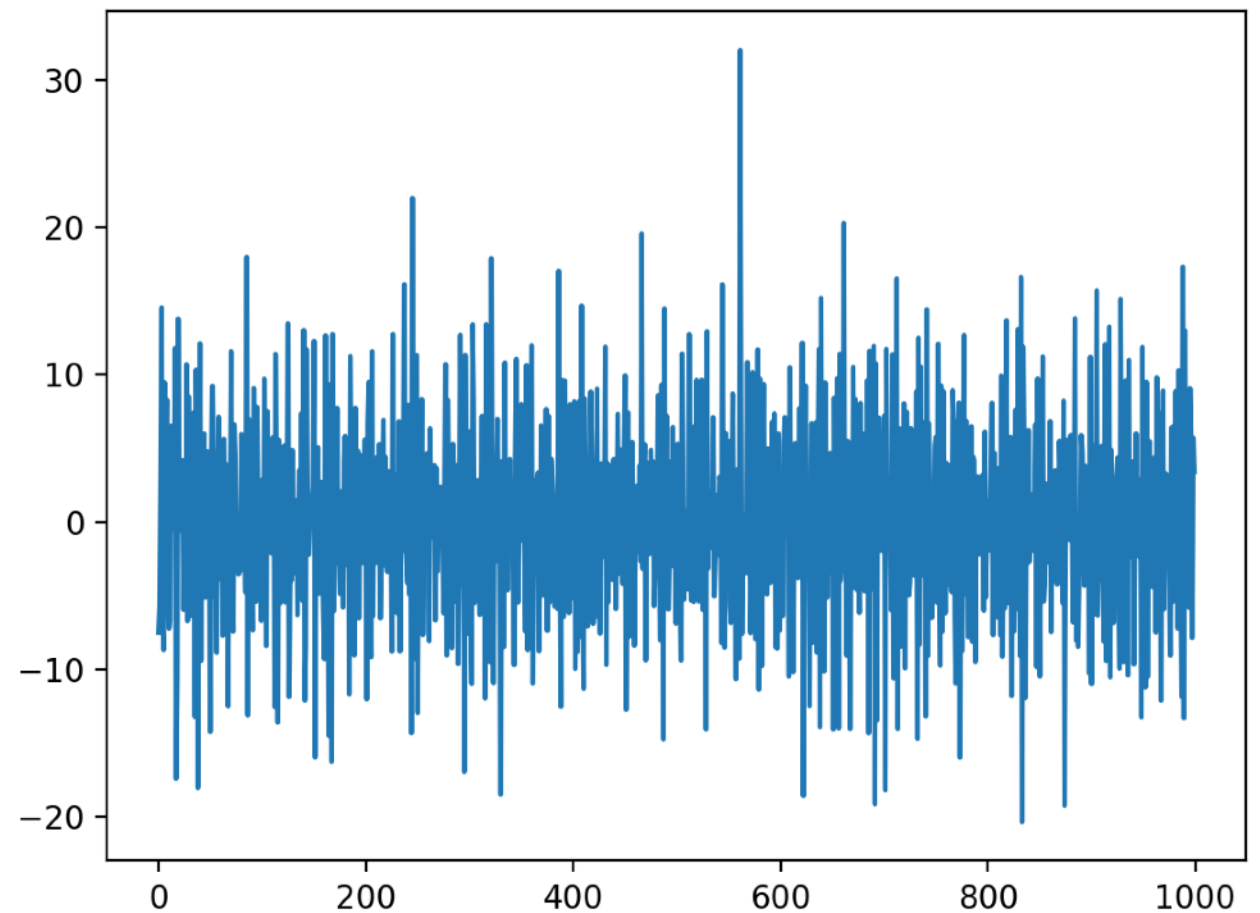
- Simulated data - particle detector.
- Signal decays exponentially when hit by particle.
- Noise is white.
- Where/how energetic were the particles that hit?



Simulated data of exponential-decay detector hit by particles.

Deconvolution

- Simplest attempt is to deconvolve observed data using exponential response.
- How might this work or not work? Why?



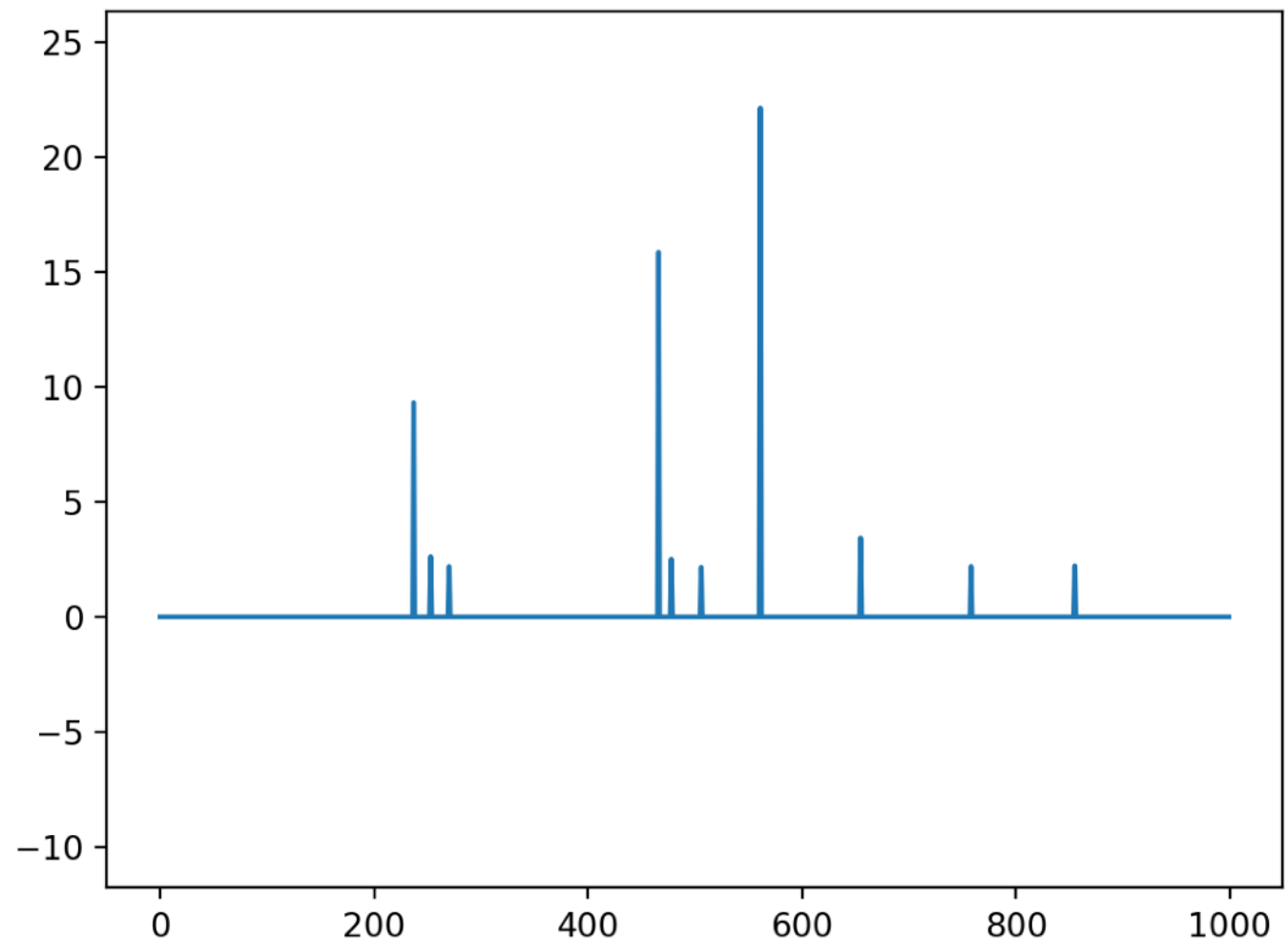
Deconvolved version of previous

Matched Filter

- We want to search for a signal in data. We don't know where it will be. How do we find it?
- Best fit amplitude for 1-D template A is $A^T N^{-1} d / A^T N^{-1} A$
- We can search many possible locations of template with matched filter, replacing top by correlation of A with $N^{-1} d$ (or $N^{-1} A$ with d) if noise is stationary
- Alternatively, could take correlation of $N^{-1/2} A$ with $N^{-1/2} d$. What would the noise in $N^{-1/2} d$ look like?
- Relevant operation is cross-correlation, not deconvolution.

MF Output

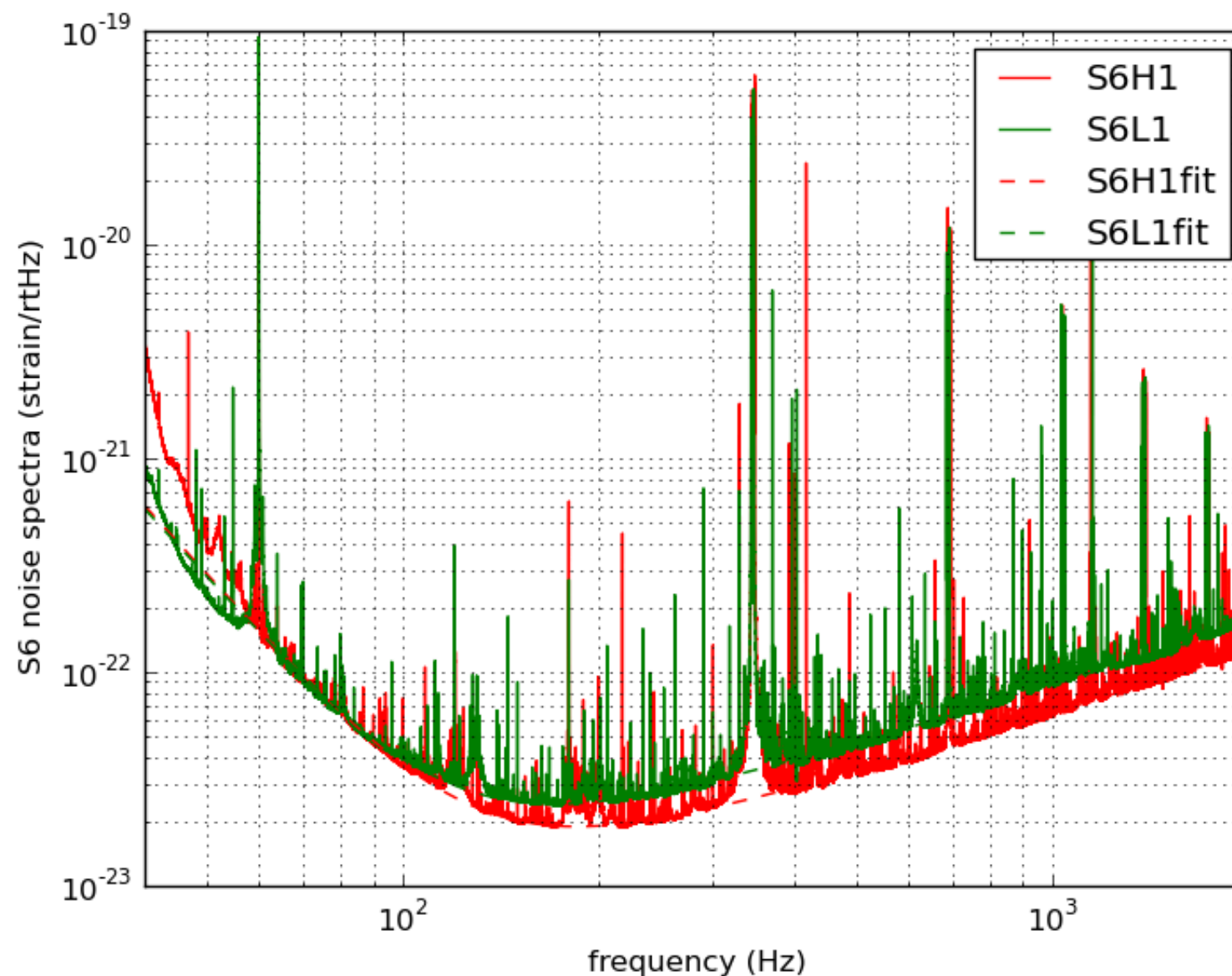
- Output of MF, vs. true input signal.
- In this case, SNR of MF is twice that of deconvolution.
- MF *multiplies* by noise, deconv. *divides*. MF stays stable in presence of zeros in noise.



LIGO Data

- <https://www.gw-openscience.org/tutorials/>
- Download: “file with data” will get you everything
- `simple_read_ligo.py` will read for you (once you have h5py installed and working)

First, what should we see for noise?



Power Spectrum Description

- Modes are uncorrelated in Fourier space
- SNR^2/mode is set by $(\text{template FT})^2/\text{noise PS}$
- Noise PS is just FT of correlation function

Fourier Interpretation

- Noise model has same total variance independent of correlation length.
- Looking at FT, long length packs noise power into many long wavelengths. Template has more power on high-frequency scales (good SNR)
- Short length spreads out power over many many modes, dropping average noise power. Template well above noise on large scales (good SNR).
- Intermediate packs all its noise into same scales as template. Never have good SNR.

When your noise looks like your signal,
you're going to have a bad day...

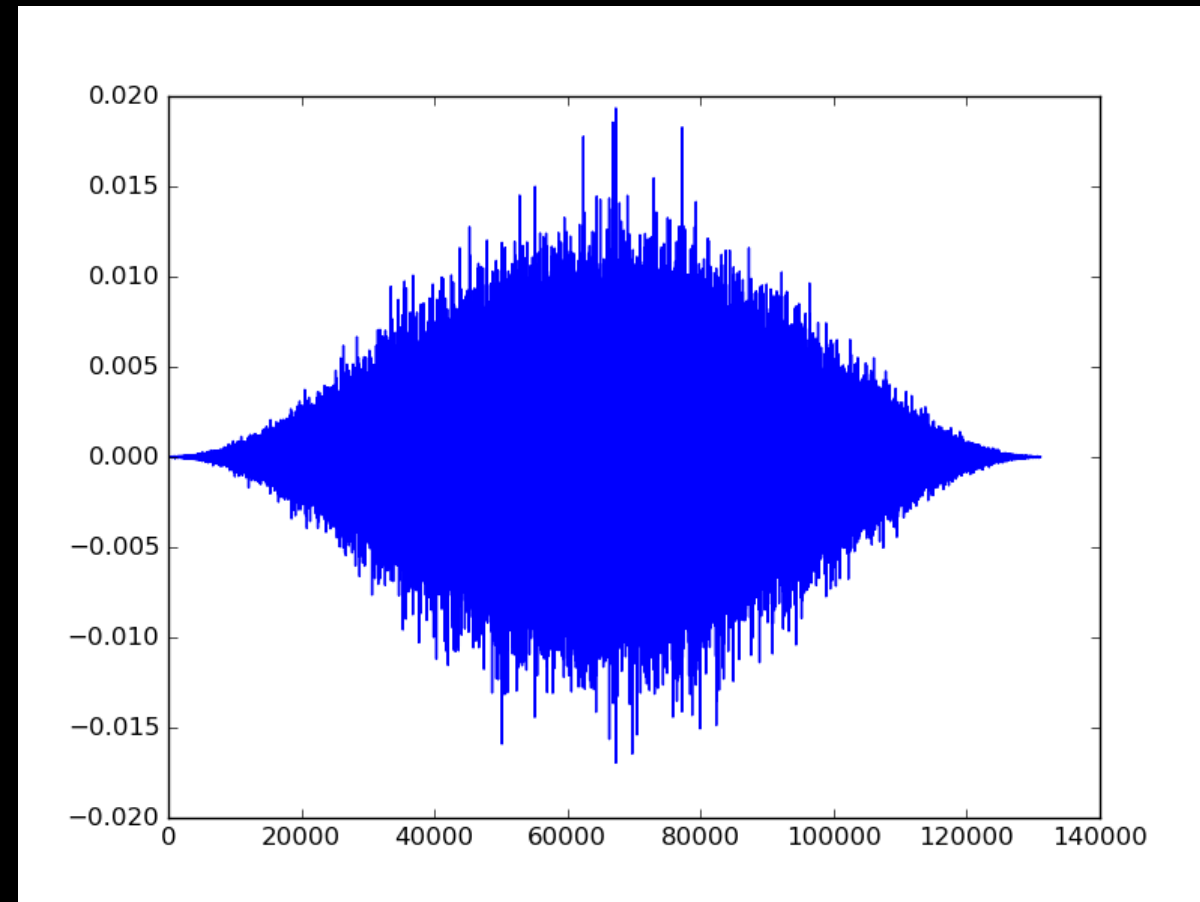
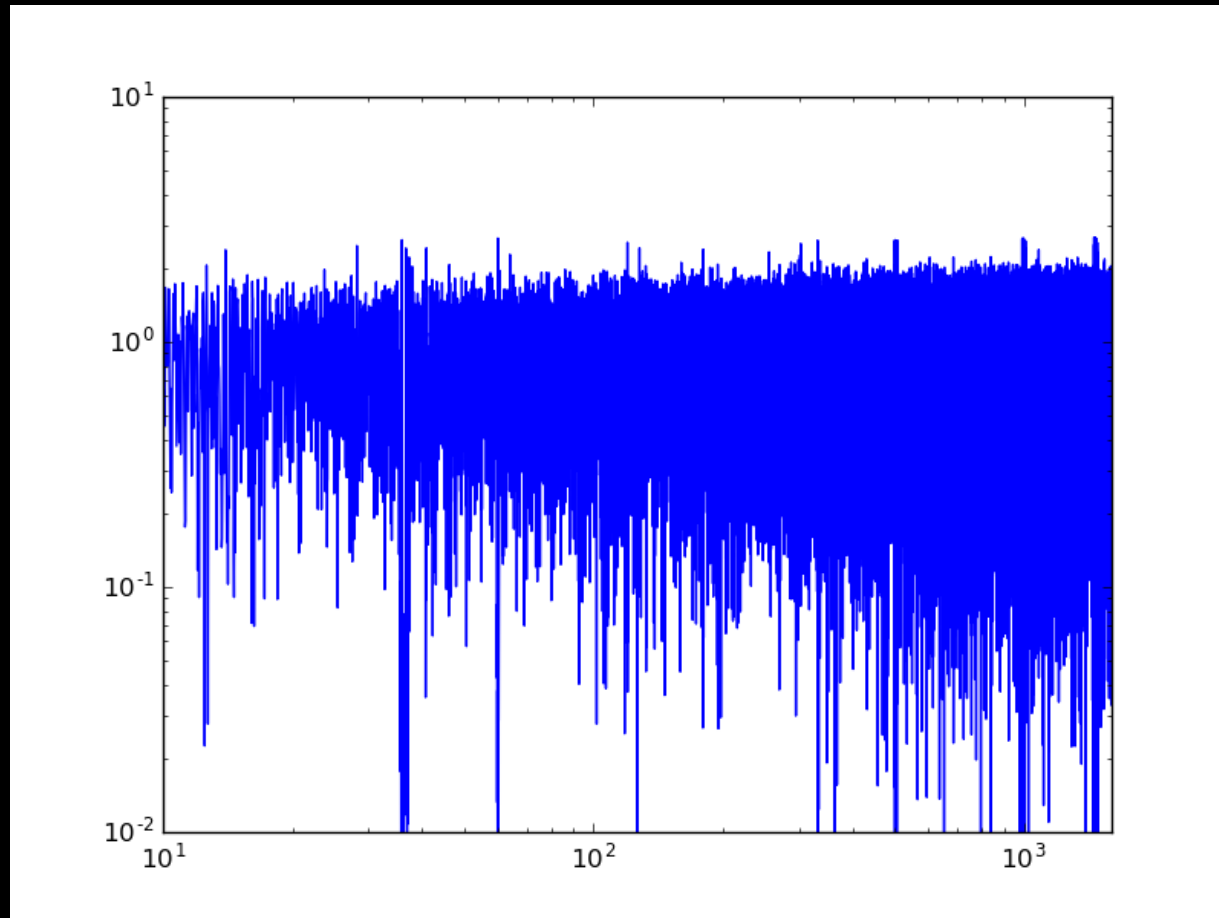
How Should We Estimate Noise?

- Windowing key to avoiding FFT ringing
- smooths out spectral features
- Noise large per mode in FT, so we have to average
- What are your thoughts on averaging?

Smoothing PS

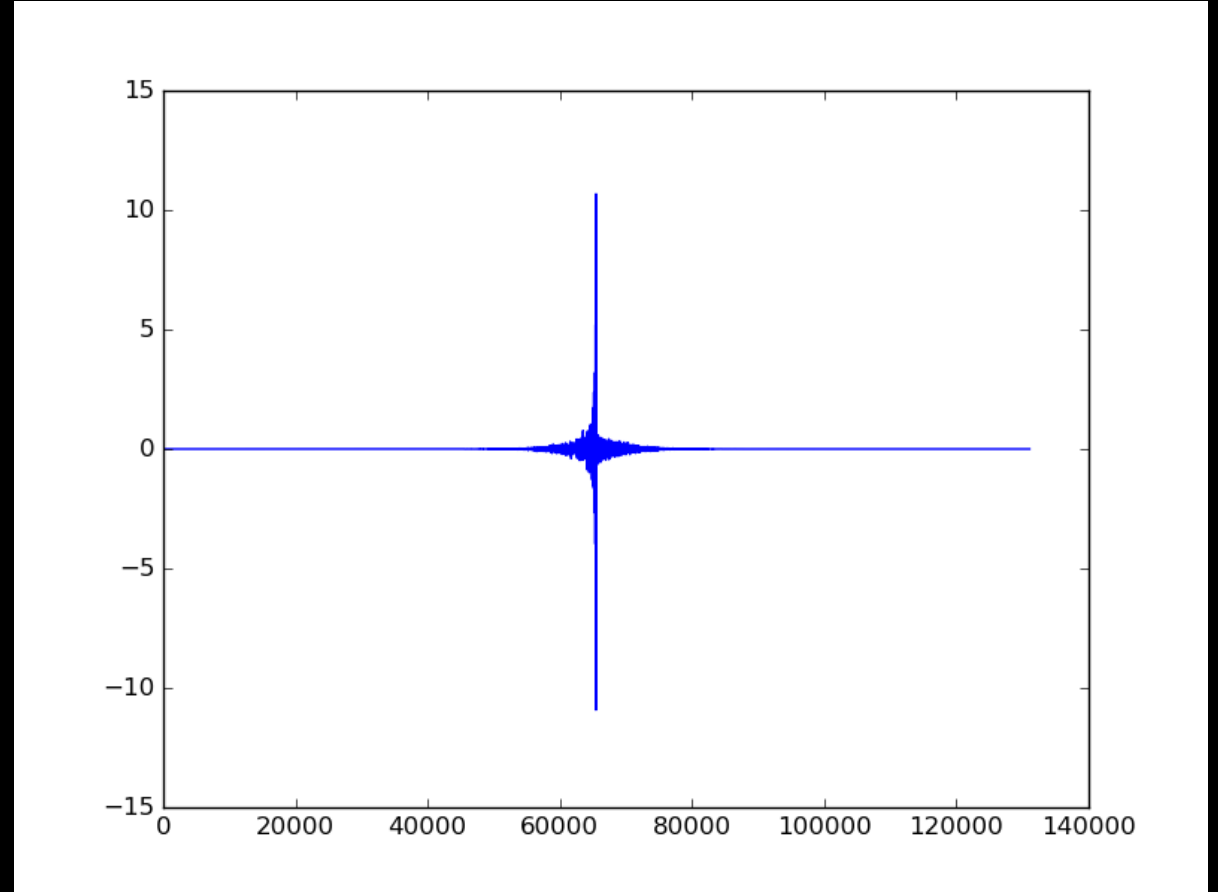
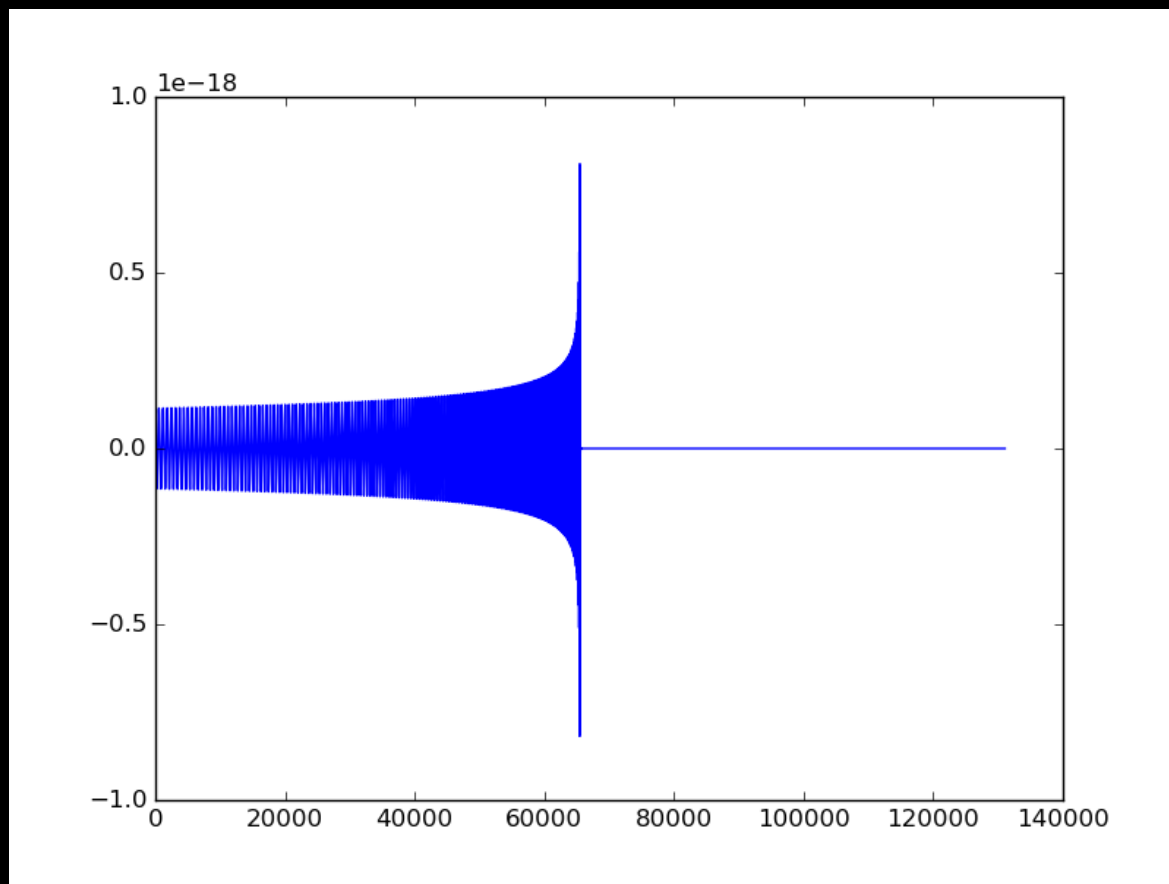
- Take $|FT|^2$, which is an estimate
- Smooth by convolving with an extended function.
- Thoughts on the function?

Pre-Whitened Data from Smoothed PS



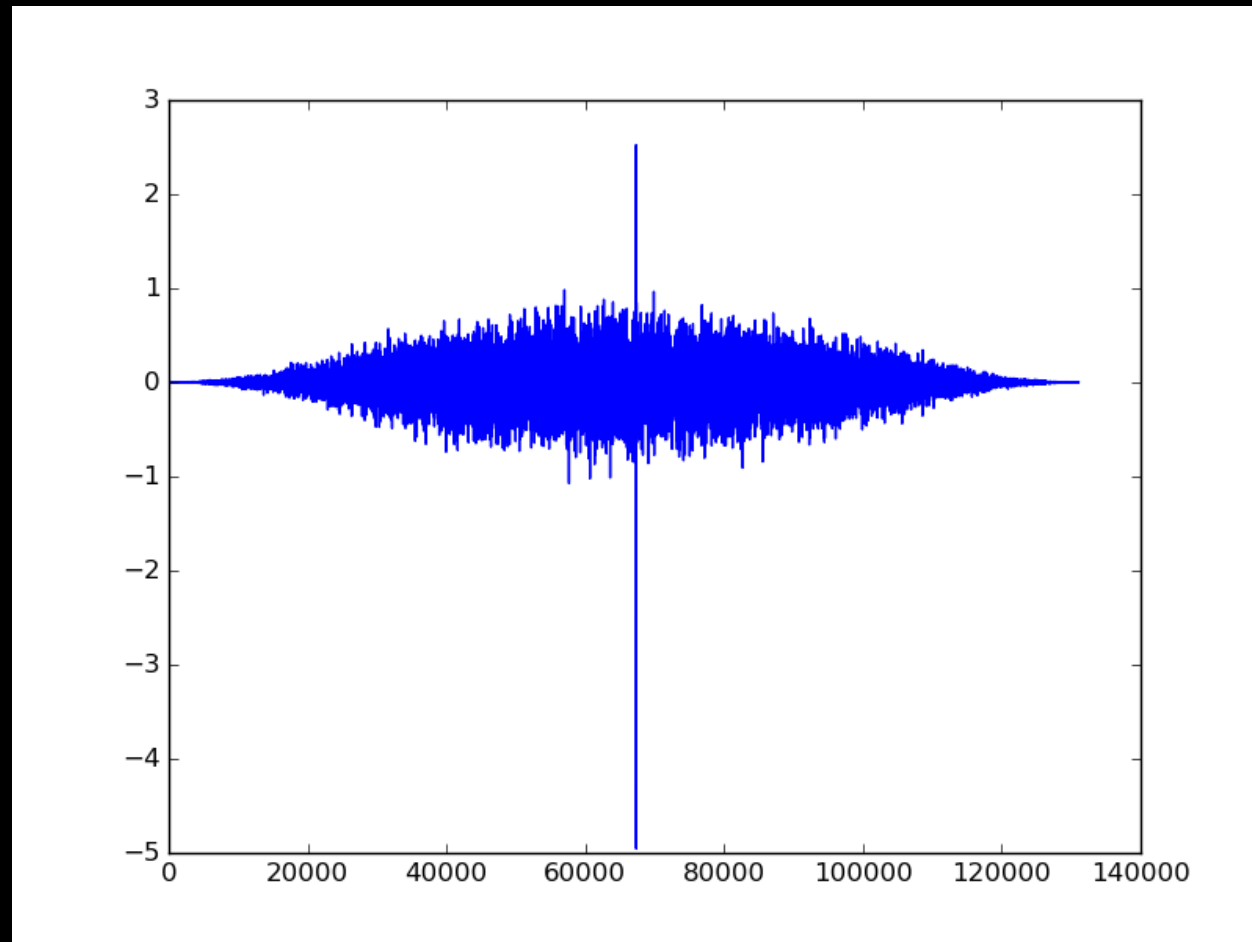
Left: Whitened FT of data. Looks not crazy. What are little nubbins sticking up?
Right: whitened data. Window shape is pretty obvious.

Pre-whitened template



- For this event, template is not small at start of data. Will this be a problem?
- Can look at pre-whitened version of template to get an idea.

Can Use for MF now



FFT Shift of matched filter output. We found a GW!

Averaging PS

- Break PS up into small chunks so we have many
- Take the FT of each chunk
- Add the FT²s together.
- How do we apply this (short) PS to original data?
- Qualitatively, how do we relate this PS estimate to smoothed one?

More Windowing

- Usual windows taper every sample.
- Reduces power in a way we probably aren't happy with
- How could we modify window to make this less of an issue?
- Let's try this on data...