The Viterbi algorithm-SOAP

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The article…

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Generalized application of the Viterbi algorithm to searches for continuous gravitational-wave signals

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All-sky and wide parameter space searches for continuous gravitational waves are generally template-matching schemes which test a bank of signal waveforms against data from a gravitational wave detector. Such searches can offer optimal sensitivity for a given computing cost and signal model, but are highly-tuned to specific signal types and are computationally expensive, even for semicoherent searches. We have developed a search method based on the well-known Viterbi algorithm which is model-agnostic and has a computational cost several orders of magnitude lower than template methods, with a modest reduction in sensitivity. In particular, this method can search for signals which have an unknown frequency evolution. We test the algorithm on three simulated and real data sets: gapless Gaussian noise, Gaussian noise with gaps and real data from the final run of initial LIGO (S6). We show that at 95% efficiency, with a 1% false alarm rate, the algorithm has a depth sensitivity of ~33, 10 and 13 $\mathrm{Hz}^{-1/2}$ with corresponding SNRs of ~60, 72 and 74 in these datasets. We discuss the use of this algorithm for detecting a wide range of quasimonochromatic gravitational wave signals and instrumental lines.

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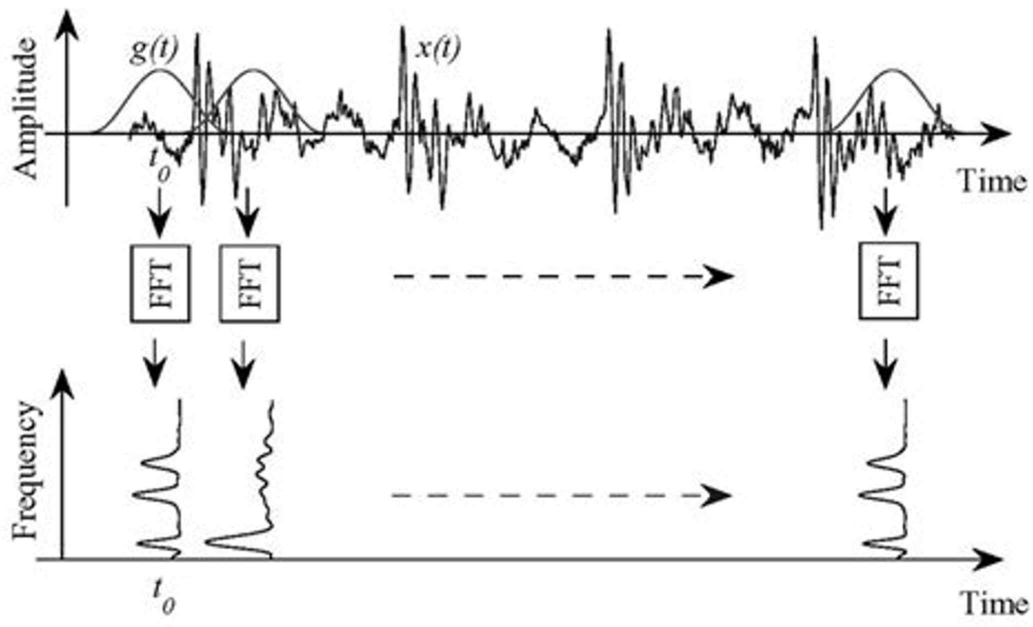
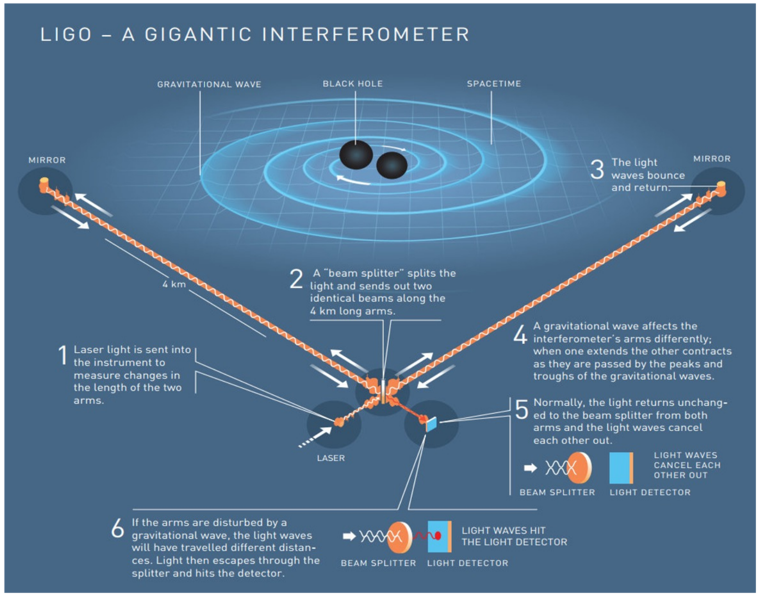
Introduction to data: Time Series

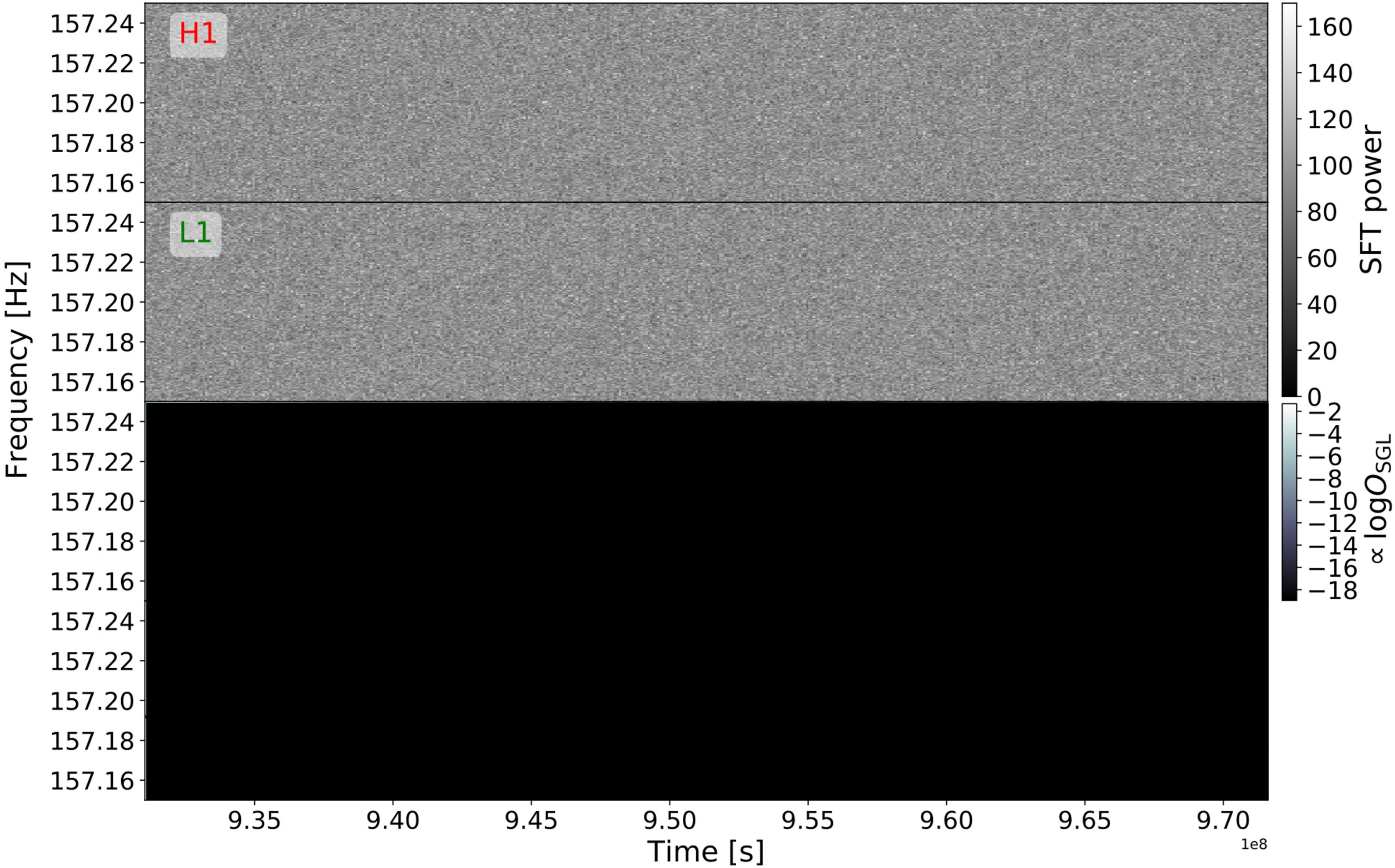
In our case the time series is signal strength versus time

SFT - Short (time) Fourier Transform

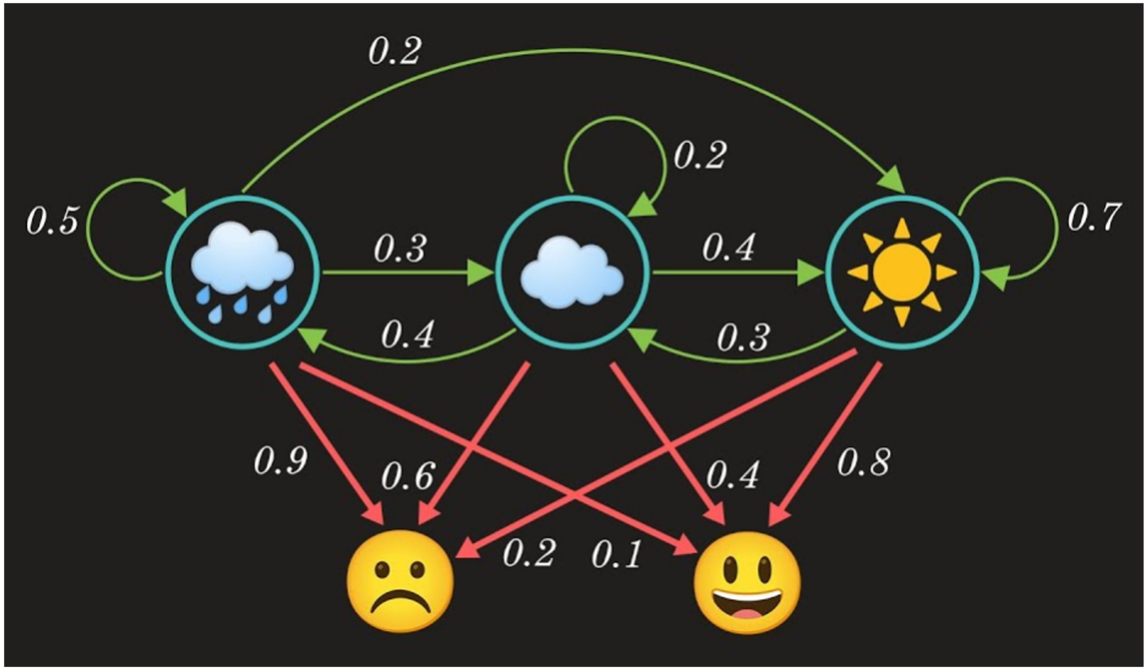




Introduction to data: Time Series/ spectrogram



Hidden Markov Models



Viterbi
$$P(\vec{\nu}|D) = \frac{P(D|\nu)P(\nu)}{P(D)} \quad (1.1)$$

Markov property
$$P(\vec{\nu}) = P(\nu_0)\prod_{j=1}^{N-1} P(\nu_j|\nu_{j-1}) \quad (1.2)$$

Log
$$\ln P(\vec{\nu}) = \ln P(\nu_0) + \sum_{j=1}^{N-1} \ln P(\nu_j|\nu_{j-1}) \quad (1.3)$$

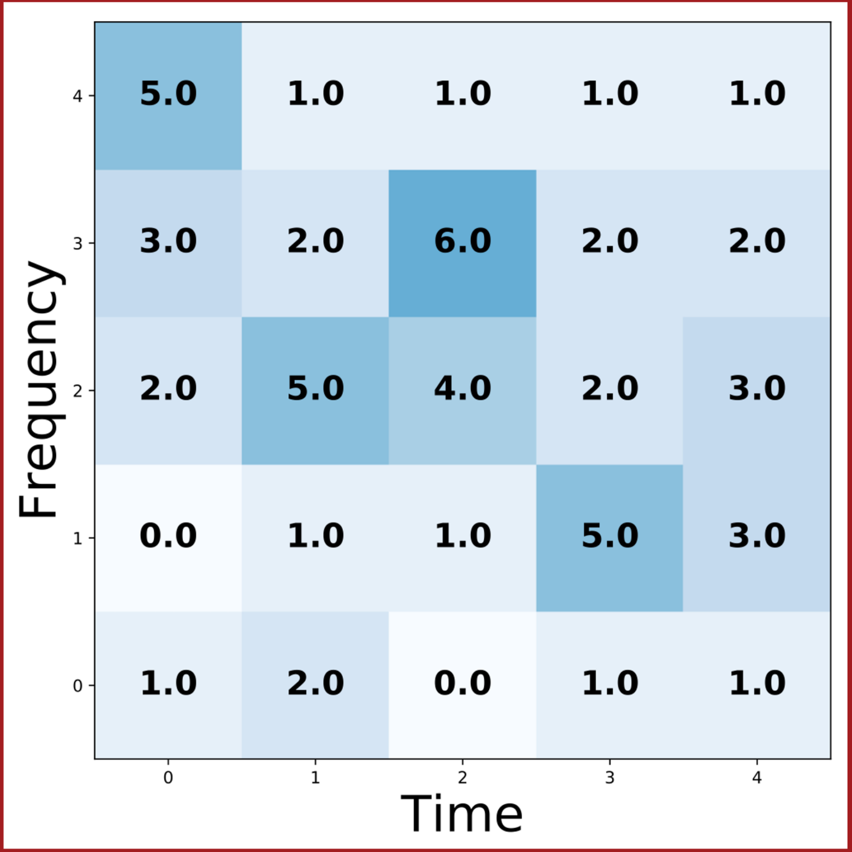
The Viterbi algorithm

The basis of this Viterbi is

- Scaled log likelihood
- "Transition matrix"

$$T = [0, 1, 0]$$

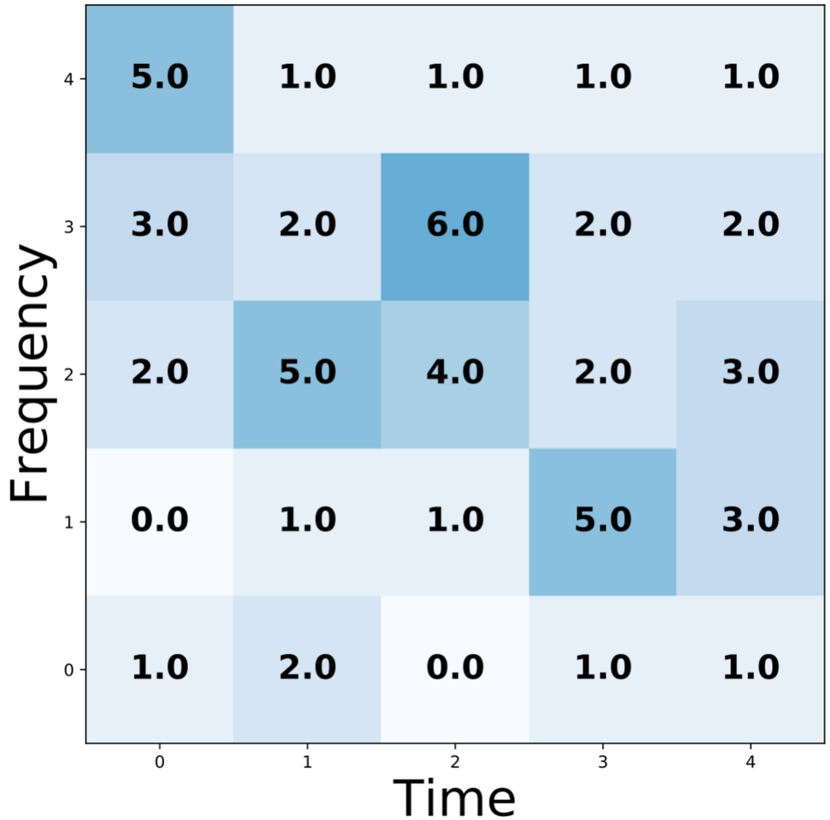
More on the less simple version later :)

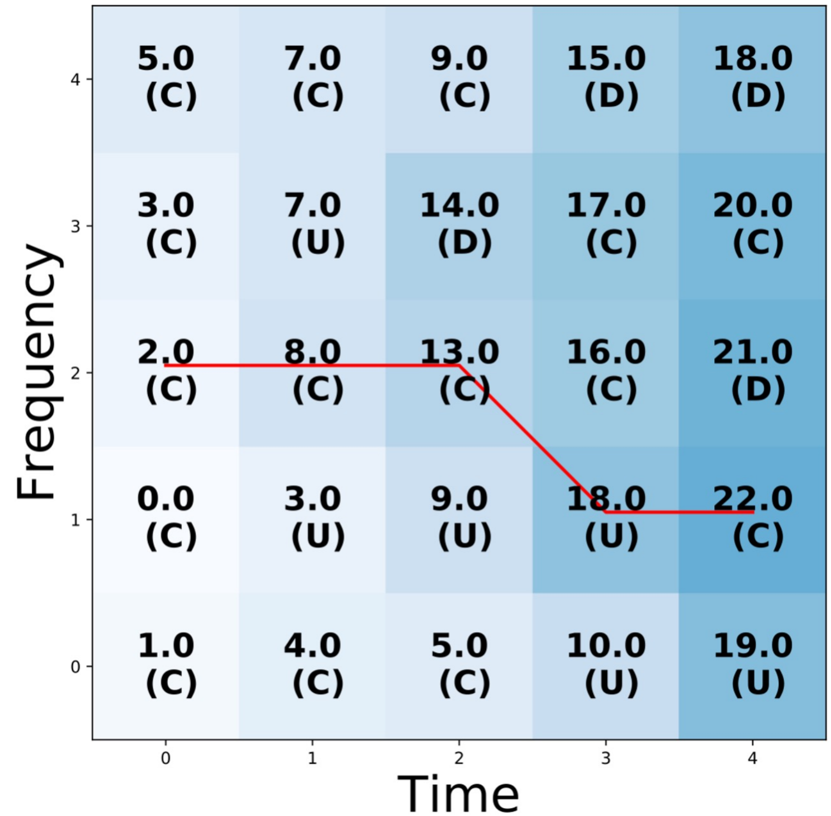


$$\ln P\left(\nu_j - \nu_{j-1} = [D, C, U] \,|\, \nu_{j-1}\right) \propto T \equiv [0, 1, 0]$$

Track construction

$$T = [0, 1, 0]$$





Modifications of the algorithm

$$P\left(\nu,\nu^{(1)},\nu^{(2)}|D^{(1)},D^{(2)}\right) \propto P(\nu)P\left(\nu^{(1)},\nu^{(2)}|\nu\right)P\left(D^{(1)}|\nu^{(1)}\right)P\left(D^{(2)}|\nu^{(2)}\right)$$

Multiple detectors

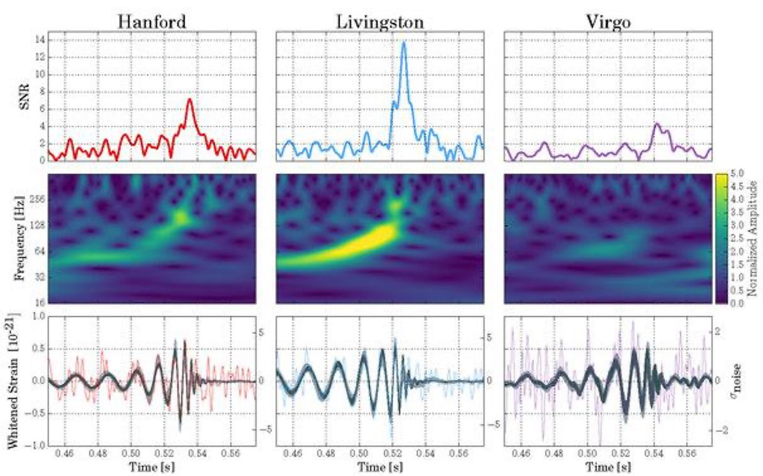
- Correct for dobbler shift
- Noise reduction

Memory

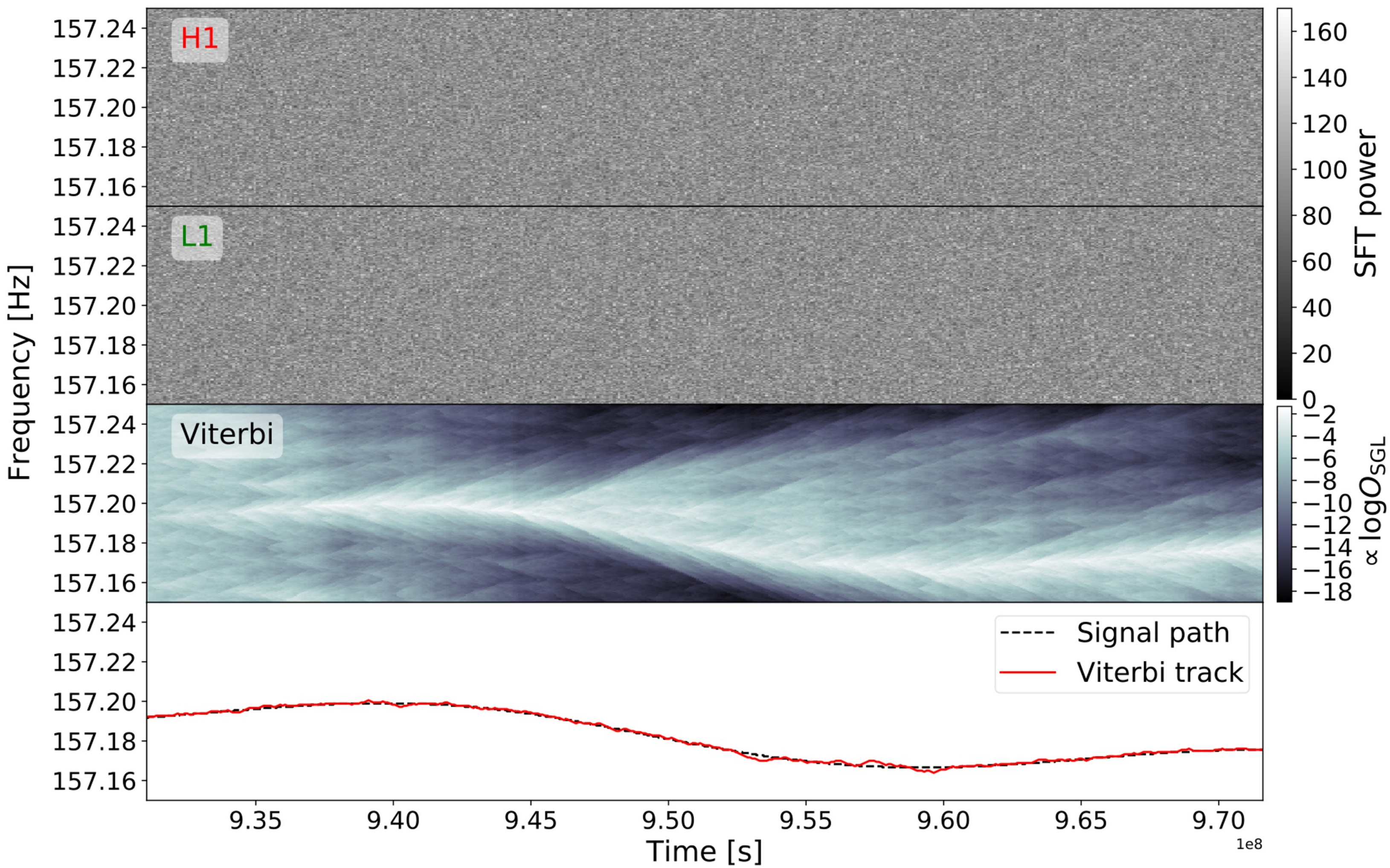
- Corresponds to increased state space
- Transition matrix

Line aware statistics

- Measurement error
- Log odds



The Viterbi algorithm applied to simulated data



Results

Better computation

Computational benchmarks

Model Agnostic

Outlook /Perspectivation/ Other applications

Originally invented to decode noisy bit channels.

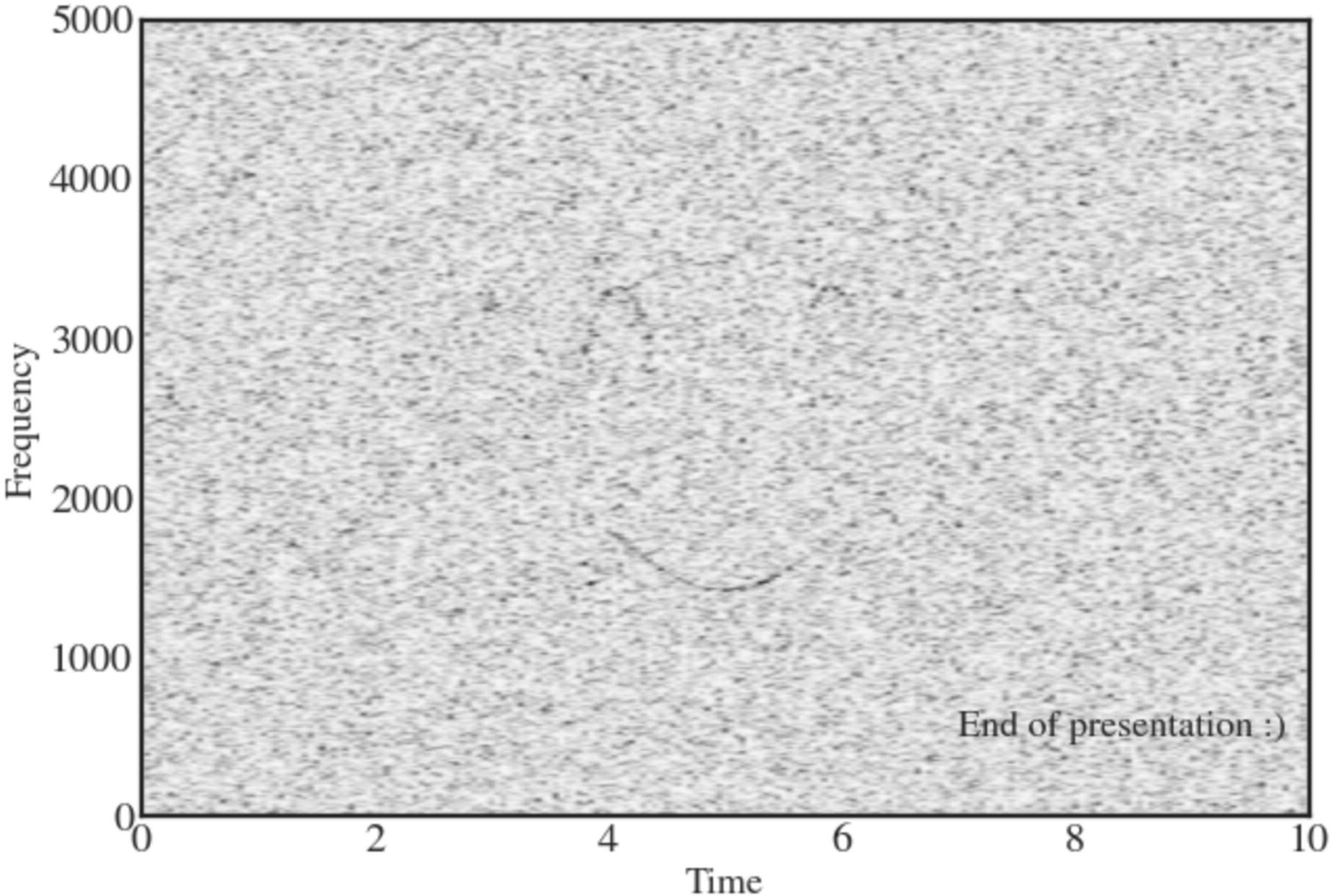
- https://ieeexplore.ieee.org/document/1054010/

Natural Language Processing

- https://arxiv.org/abs/cmp-lg/9406003

DNA Sequencing

- https://arxiv.org/abs/1012.0900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Frequency
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6
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Time
End of presentation :)