Searching for Gravitational Wave Bursts of Arbitrary Waveform

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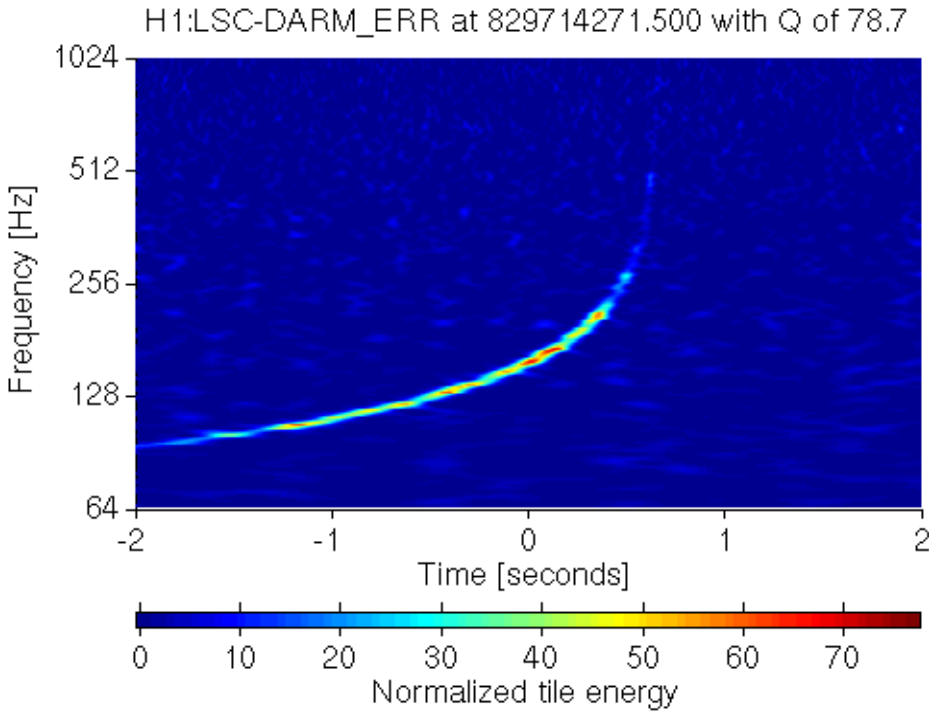
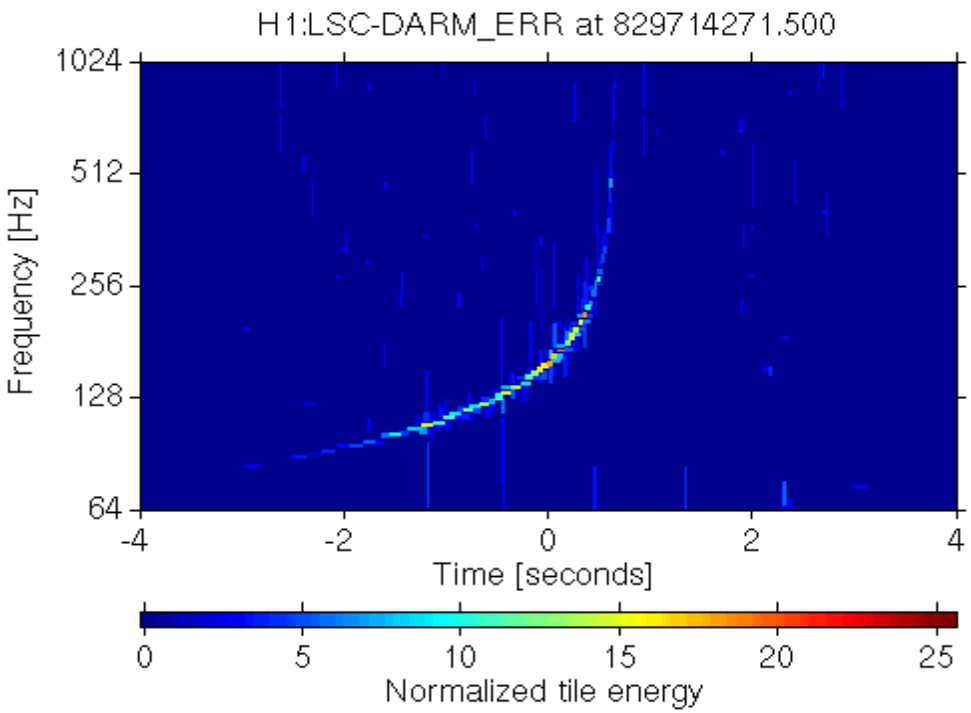
Burst Sources

- Bursts: Short lived transient events, often of unknown waveforms
- Modelled Waveforms:
  - Inspiral Phase of Binary Merger, Ringdown etc.
  - Use Matched Filtering.
- Unmodelled Waveforms:
  - Supernovae, Binary Compact Object Merger, GRB, time-frequency excess signal energy etc.
  - Use Cross Correlation.

Q Pipeline

- Q Pipeline: time-frequency search algorithm for bursts
- Equivalent to matched filter for sine-gaussian
- Tiles the targeted signal space with the minimum number of tiles necessary for searches
- Logarithmic in frequency, linear in time



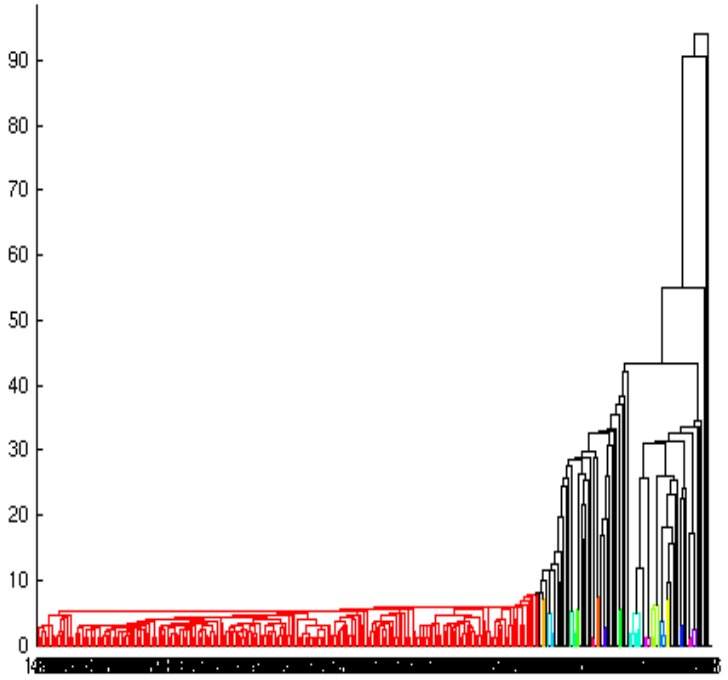


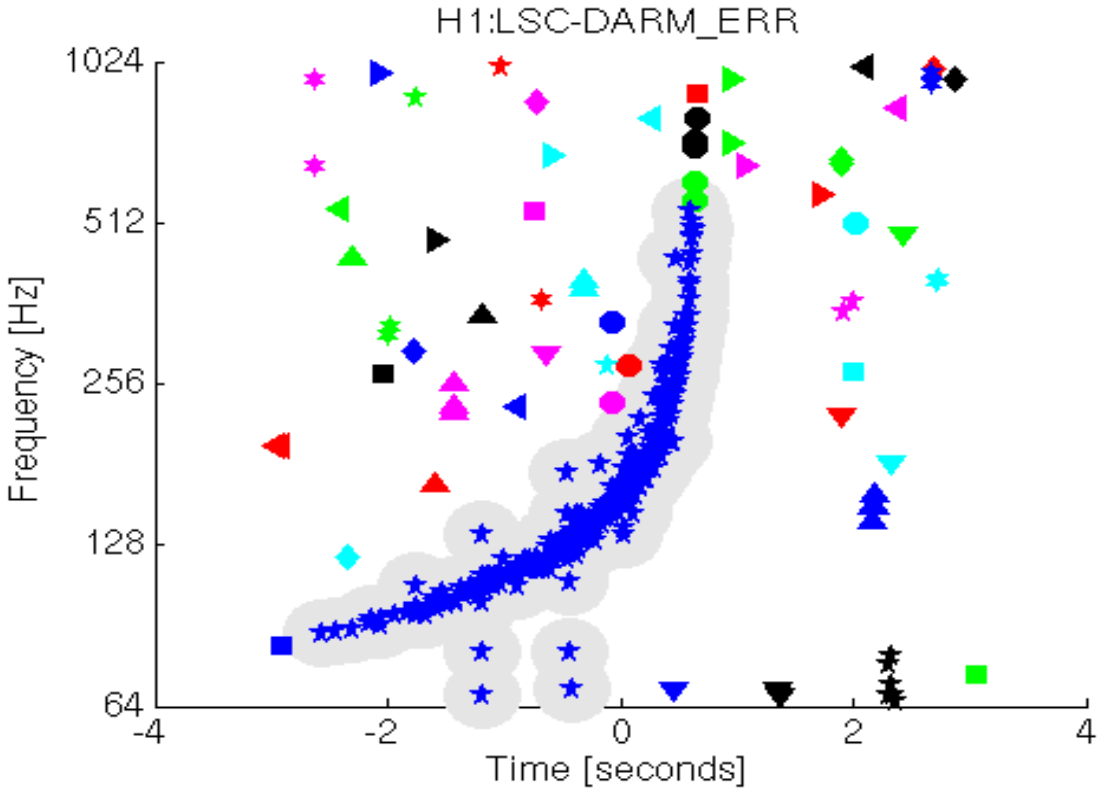
Motivation for Clustering

- Q pipeline treats each tile as an individual event
- Minimum uncertainty tiles picked by Q pipeline
    - Maximum signal to noise ratio
    - Minimum accidental coincidence
- May not be optimal for bursts that are non-localized on time-frequency plane
- Clustering to collect energy may help

Example: Hierarchical Clustering

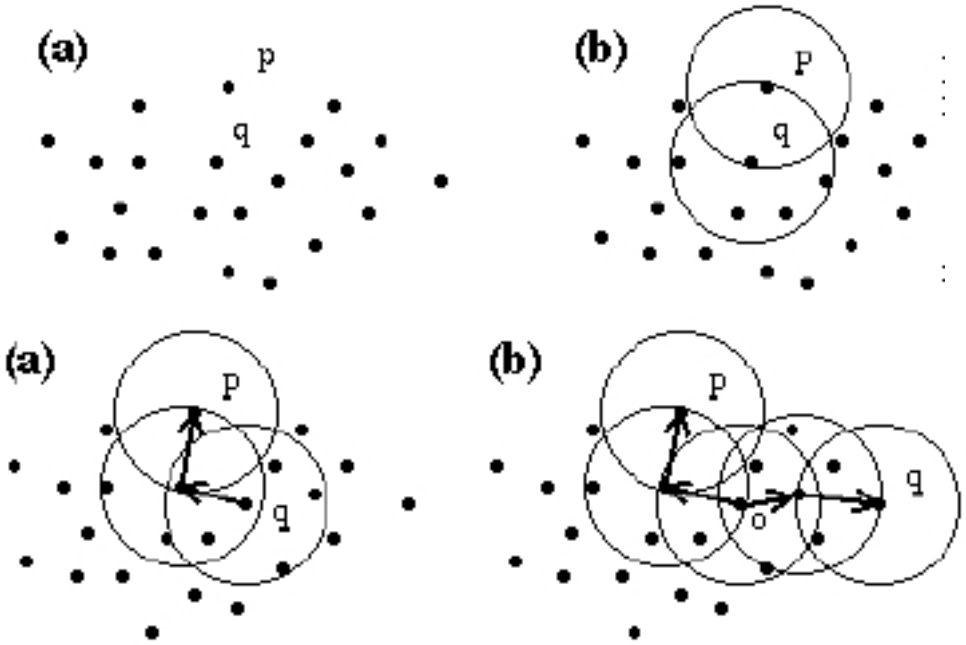
- Constructs hierarchy of tiles based on distance and threshold
- But hierarchical clustering is not good enough
- Need to reject noise, find arbitrary shapes





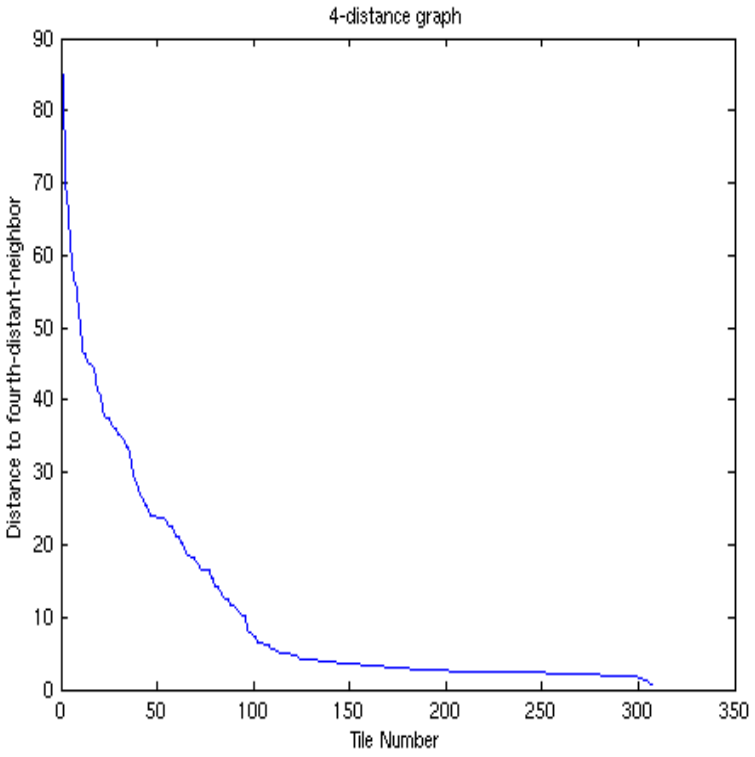
Density Based Clustering

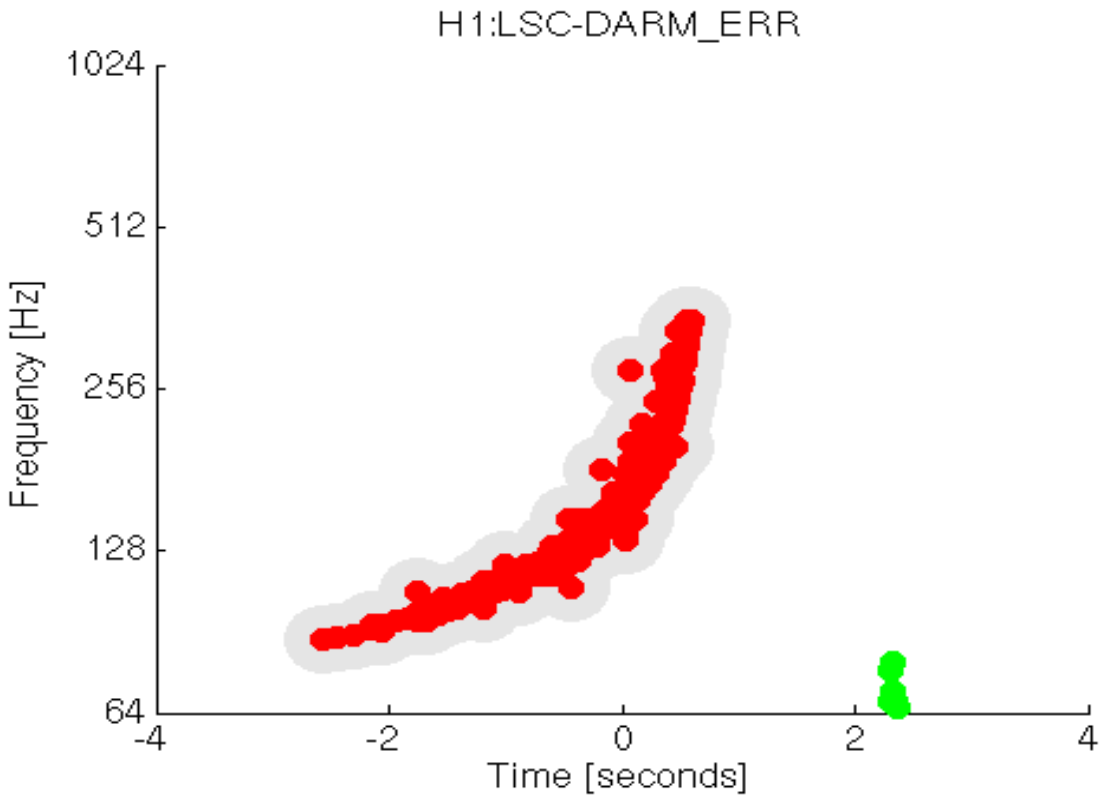
- Find neighbors, neighbors' neighbors, their neighbors …
- Two parameters: neighborhood radius, neighbor number
- M. Ester et. al., "A Density Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise", 1996.



Density Based Clustering

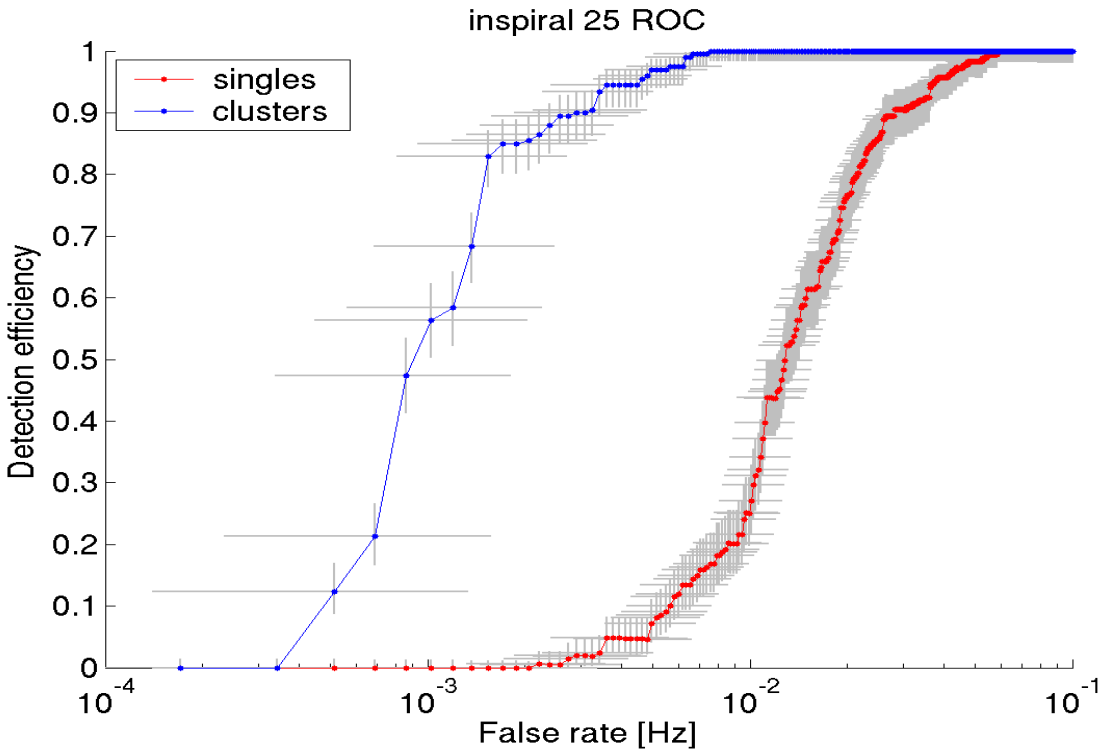
- Rejects, and thus reduces noise dramatically
- Finds arbitrary shapes
- Fast, and efficient implementation





Testing: ROC Curves

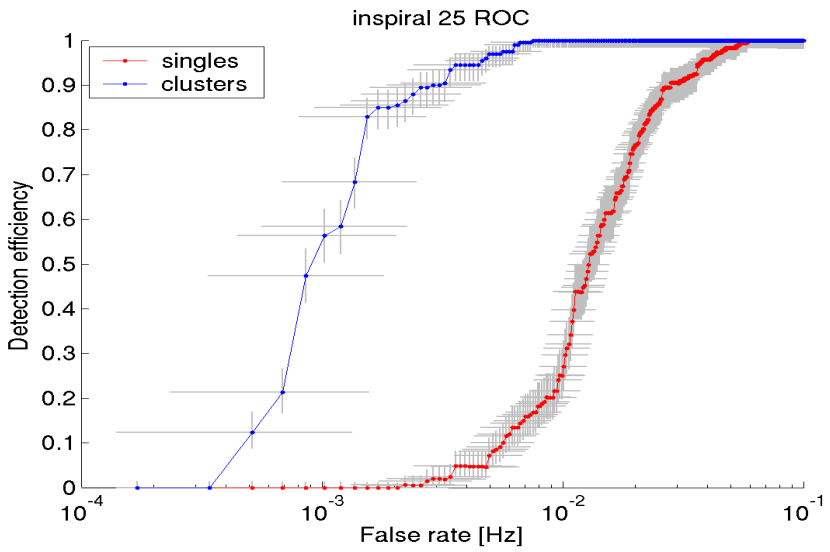
- Receiver Operating Characteristic (ROC) Curves
- Detection efficiency versus false-rate
- Red: Q pipeline without clustering (singles)
- Blue: Q pipeline with clustering (clusters)

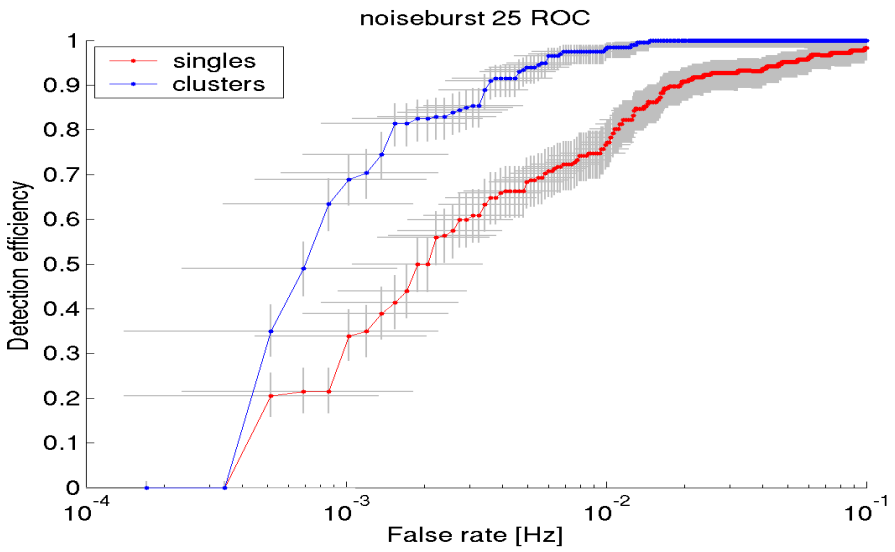


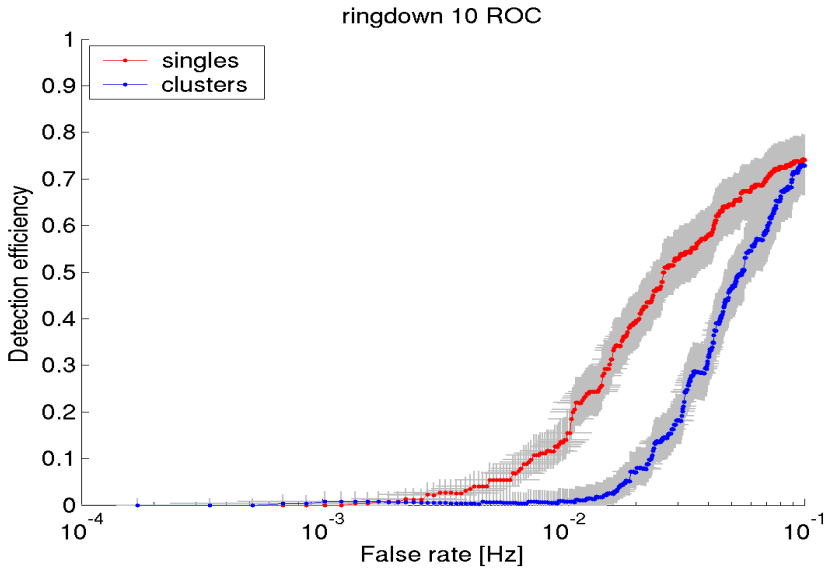
Producing ROC Curves

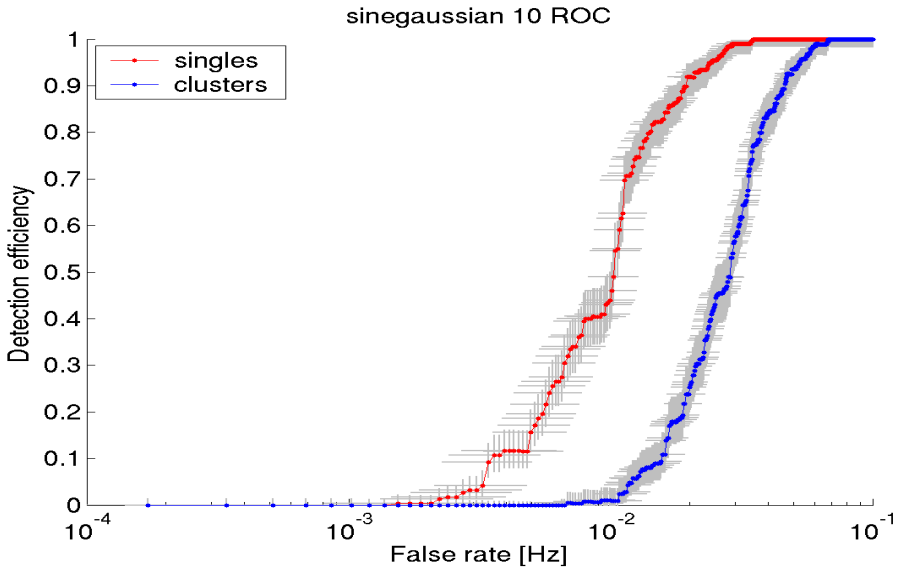
- Single detector search for 200 injections with one injection per 32 second S5 data frame
- Simulated bursts of different waveforms at constant Signal to Noise Ratio (SNR)
- Random injection time and signal parameters (i.e. frequency, duration, mass etc.)
- Five waveforms tested:
  - Non-localized Signal Waveforms
    - Inspiral, and Ring Down.
  - Localized Signal Waveforms
    - Sinusoidal Gaussian, Gaussian, and Noise Burst

ROC Curves


inspiral 25 ROC
singles
clusters
Detection efficiency
False rate [Hz]


noiseburst 25 ROC
singles
clusters
Detection efficiency
False rate [Hz]


ringdown 10 ROC
singles
clusters
Detection efficiency
False rate [Hz]


sinegaussian 10 ROC
singles
clusters
Detection efficiency
False rate [Hz]

Observations

- Clustering helps finding non-localized bursts of unknown waveforms
- Density based clustering helps finding clusters of arbitrary shapes, and rejects noise
- Our implementation of density based clustering is extremely fast and efficient
- It should significantly improve the performance of Q pipeline for non-localized signals

Future Directions

- Maintain sensitivity of Q pipeline for localized signals
- Better define cluster significance and coincidence
- Study performance for coherent and coincident searches
- Incorporate clustering in to standard Q pipeline
- Present results at GWDAW (Germany, December 2006)
- Write paper for publication and present to LSC

Thank you!

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- Albert Lazzarini
- Patrick Sutton
- Lisa Goggin
- Stephen Poprocki

Questions?