Targeted Searches using Q Pipeline

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August 18, 2005

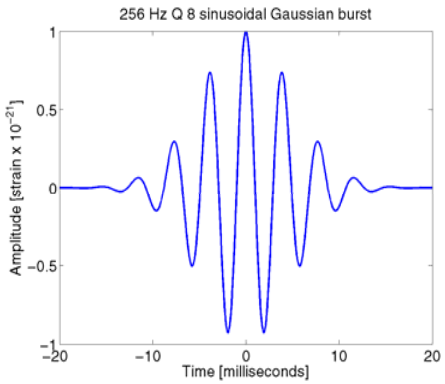
LIGO-G050469-00-R

Outline

- Overview: Burst GW Sources
- Q Transform
- Motivation
- Coherent Targeted Searches
- Consistency Checks
- Examples
- Conclusions

Bursts

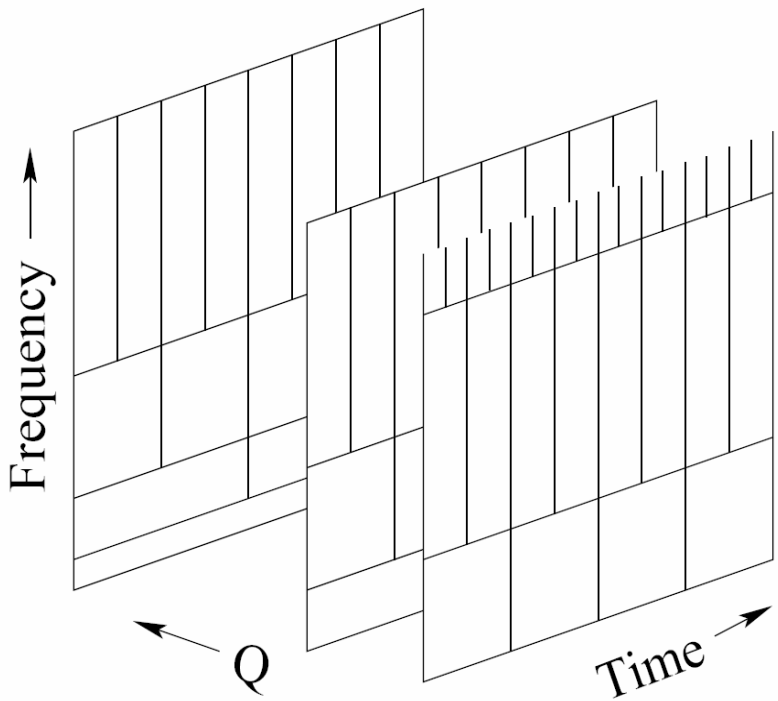
- Unknown or crudely modeled
- “Expectations”:
  - Duration: ~1-100 ms
  - Frequency: >~ 500 Hz



- Searching:
  - Matched Filter: Project data onto known waveform
  - Cross-correlation: Project data stream from one detector onto another
  - Time-Frequency: Project data steam onto a basis of waveforms designed to cover the targeted signal space

Q Transform

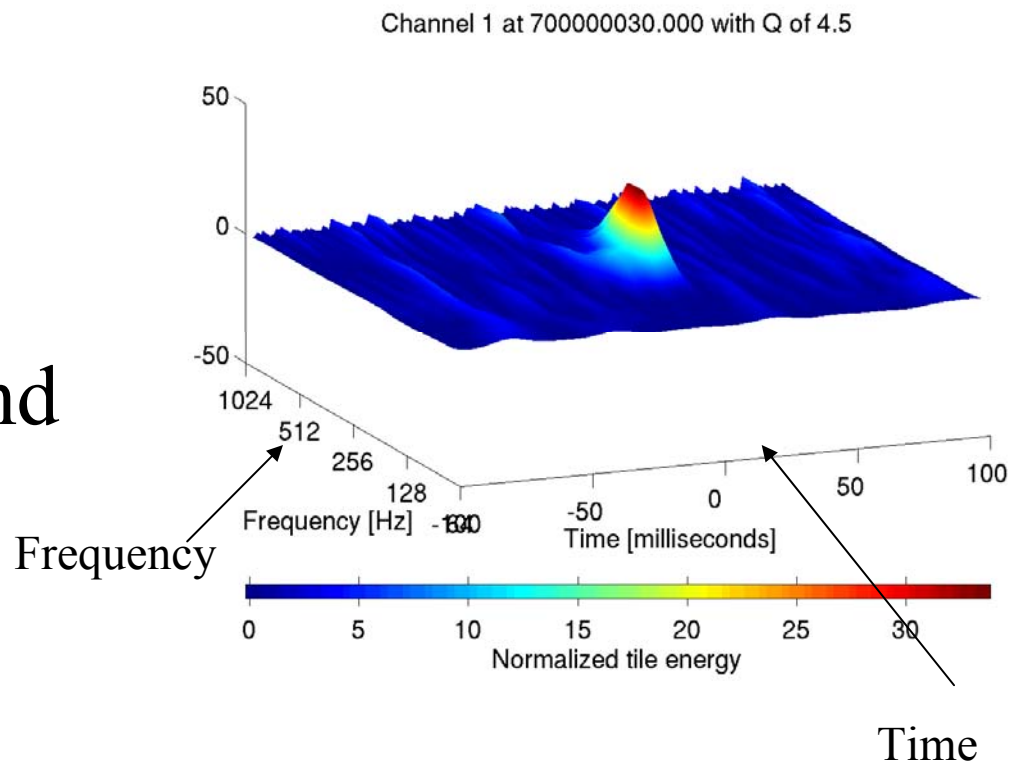
- Multi-resolution basis
- Time, frequency, Q
- $Q = f/\Delta f$
- Over-complete basis
- Purpose is detection not reconstruction
  - Logarithmic spacing Q
  - Logarithmic spacing f
  - Linear spacing in t



Q Transform

- Simulated Data
- SG235 + simulated noise
- Signal Q = 16
- Problem: Burst GW and noise can look alike
- Vetoing techniques crucial

Q = 4.5

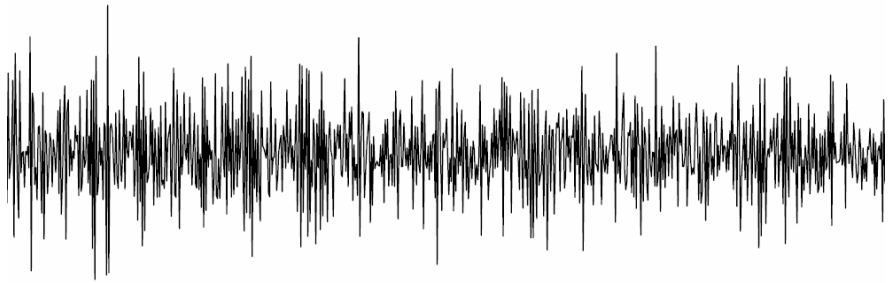


Multiple Detectors

- Coherent Sum
- Three or more needed (Gursel, Tinto, 1989)
- Achieve higher SNR using HL network
- Distinguish GW from Glitches using H1 and H2

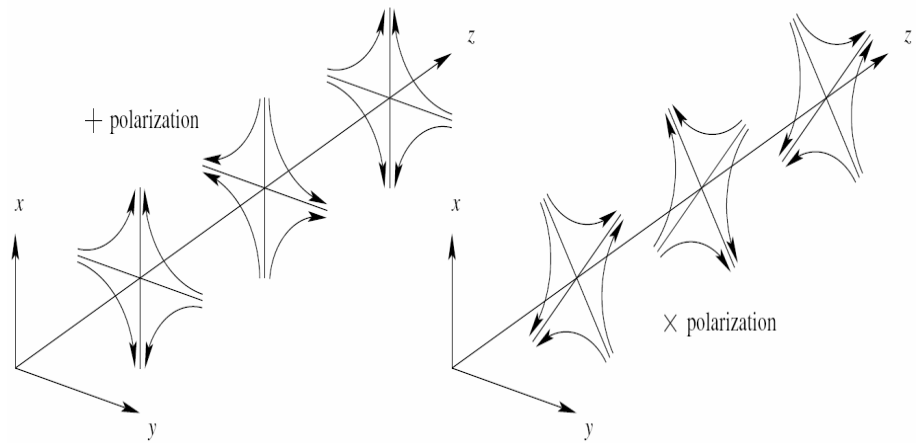
Coherent Sum

- Single detector response of form



$$h(t) = F+(\theta,\varphi)h+(t) + Fx(\theta,\varphi)hx(t) + \eta$$

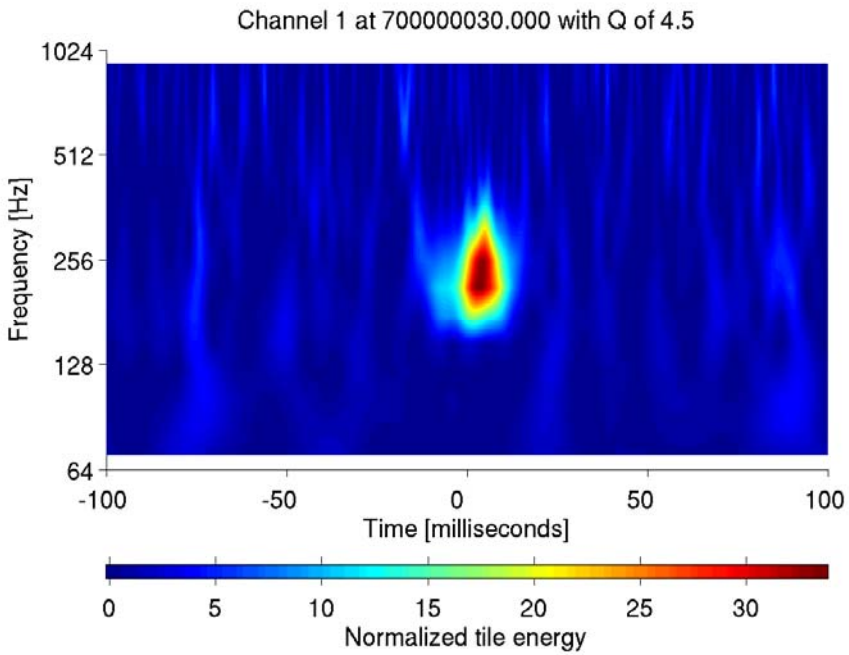
- Find set of scalar coefficients that would maximize SNR
- How much a priori information is required?

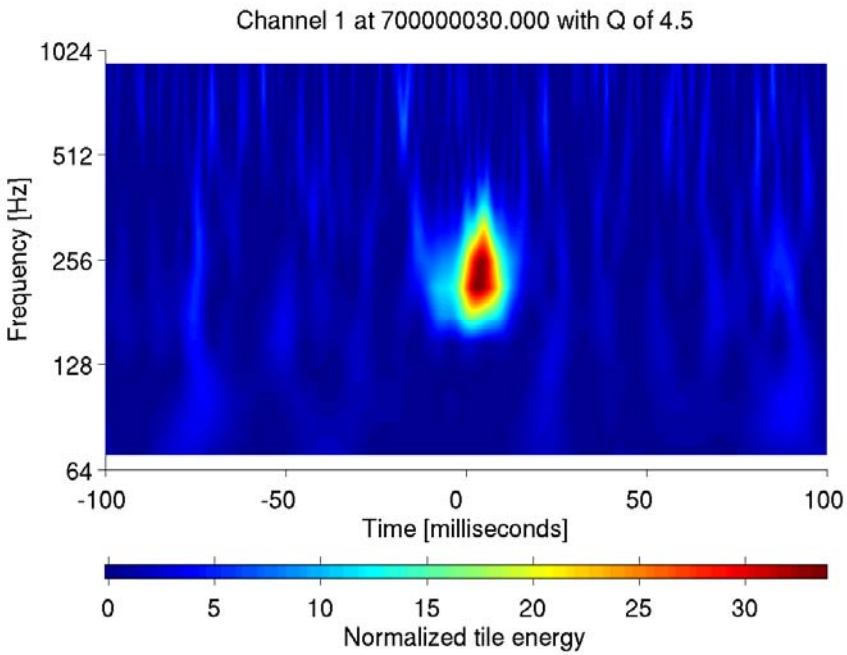


Coherent Sum

- 1) Time Shifts: GR propagates at speed c.
- 2) Amplitude Corrections: Accounts for different detector responses
- Both time shifts and detector response are a function of propagation direction
- Then for a given sky location carry out the calculations
- Sylvestre Algorithm

Time Shifts


Channel 1 at 700000030.000 with Q of 4.5
1024
512
256
128
64
Frequency [Hz]
-100
-50
0
50
100
Time [milliseconds]
0
5
10
15
20
25
30
Normalized tile energy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128
64
Frequency [Hz]
-100
-50
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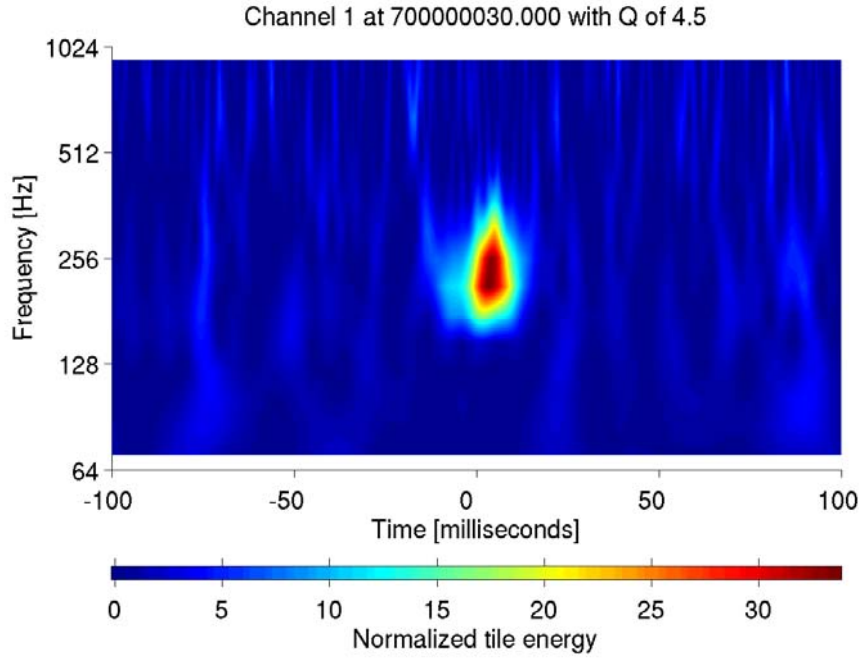
50
100
Time [milliseconds]
0
5
10
15
20
25
30
Normalized tile energy

Amplitude Scaling

- Scale each input by an unknown coefficient
- Calculate the signal and noise power of combined response
- Using the Lagrangian method maximize for SNR
- Eigenvalue problem, easily solved
- Required information about wave:
  - 1) h+ . hx Inner product of polarizations
  - 2) |h+|/|hx| Ratio of power

Example:

H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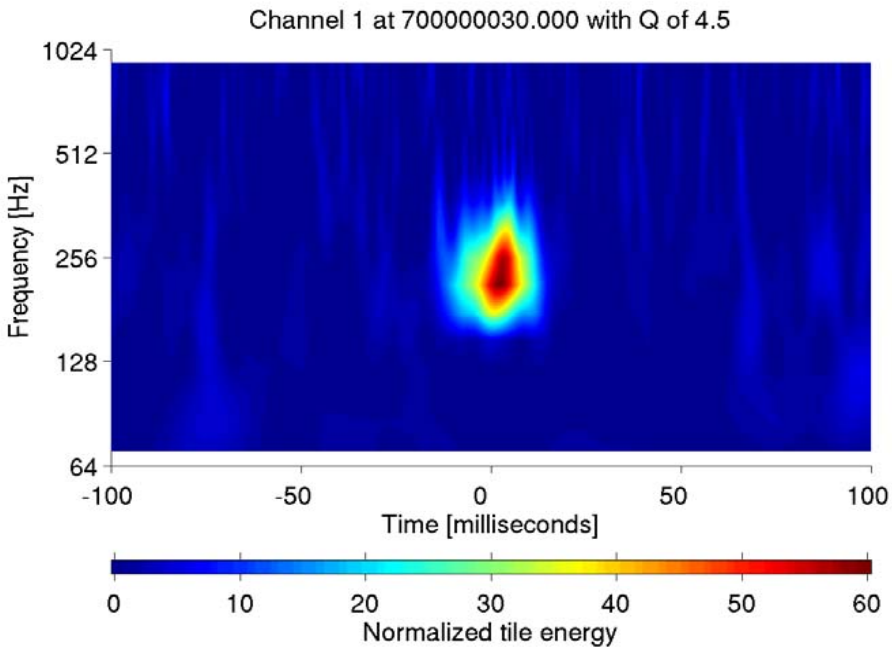
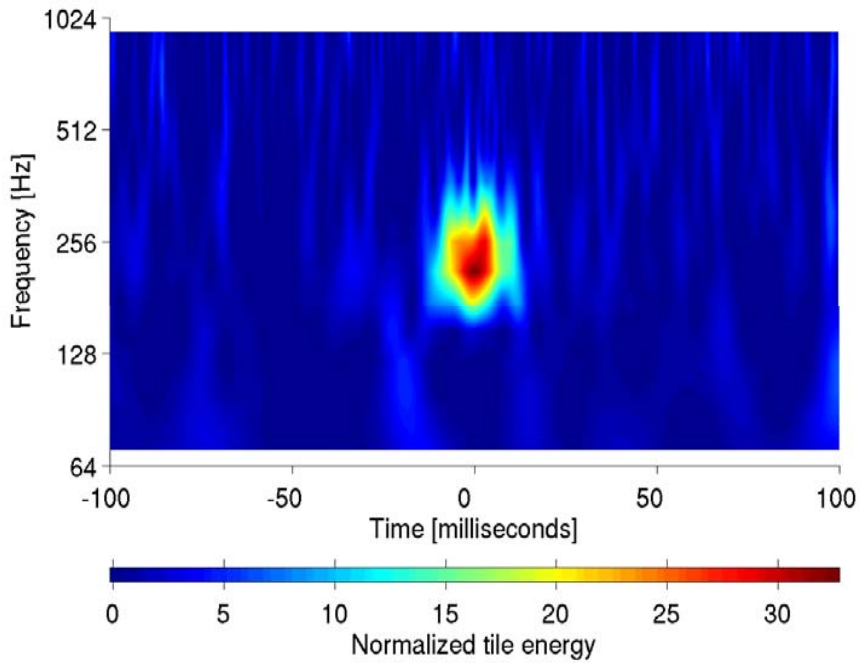
Frequency [Hz]
1024
512
256
128
64
-100
-50
0
50
100
Time [milliseconds]
0
5
10
15
20
25
30
Normalized tile energy

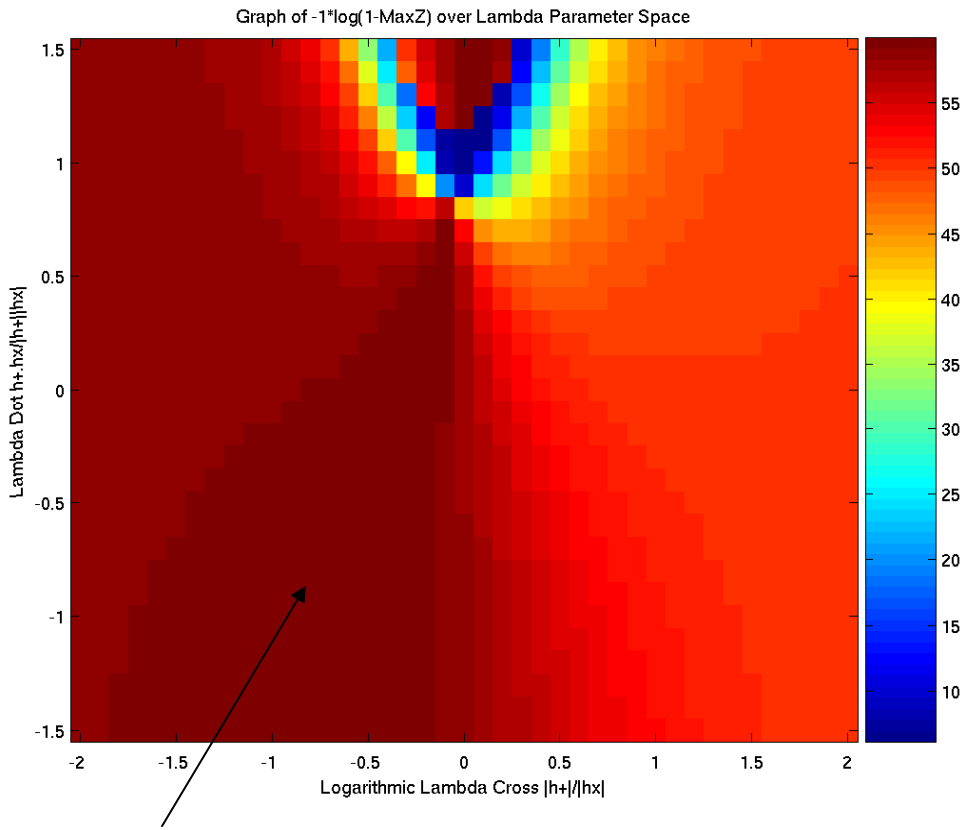
S


Channel 1 at 700000030.000 with Q of 4.5
Frequency [Hz]
1024
512
256
128
64
-100
-50
0
50
100
Time [milliseconds]
0
10
20
30
40
50
60
Normalized tile energy

L


Frequency [Hz]
1024
512
256
128
64
-100
-50
0
50
100
Time [milliseconds]
0
5
10
15
20
25
30
Normalized tile energy

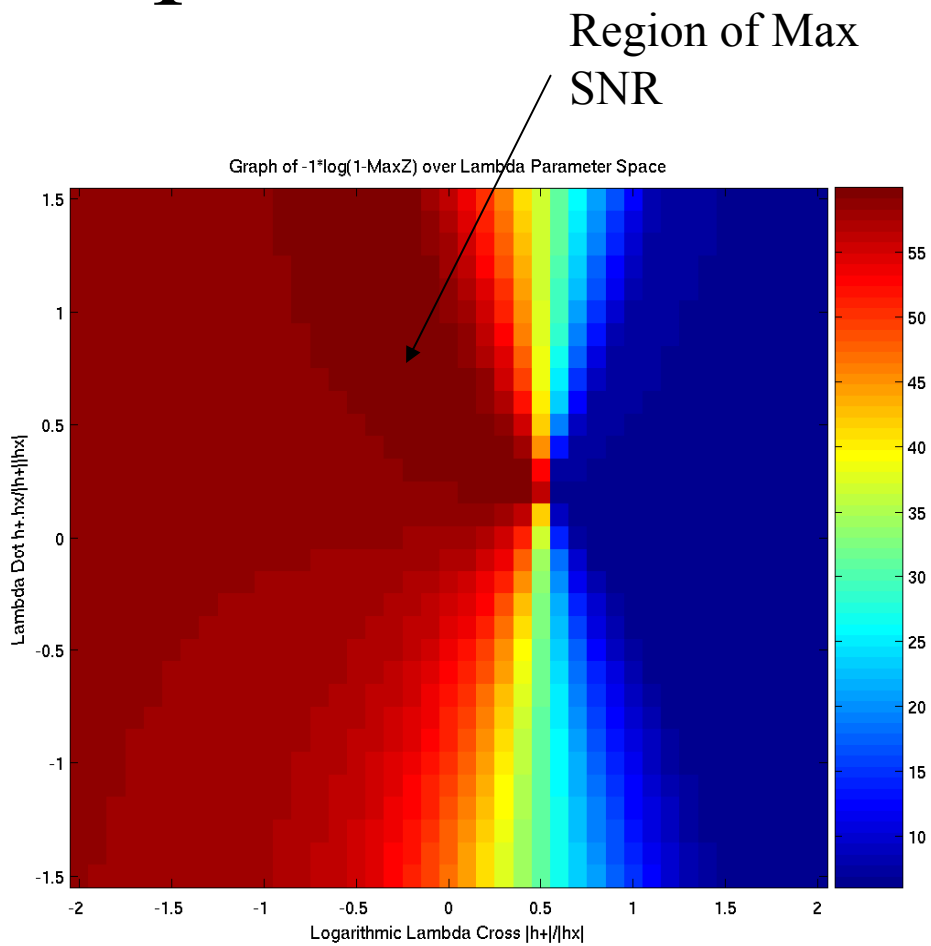
Parameter Space



Region of Max SNR

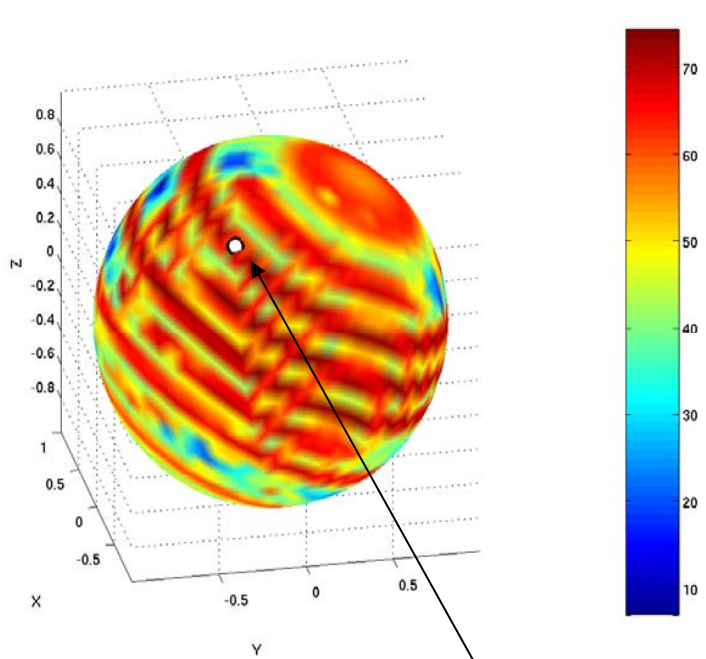
Parameter Space

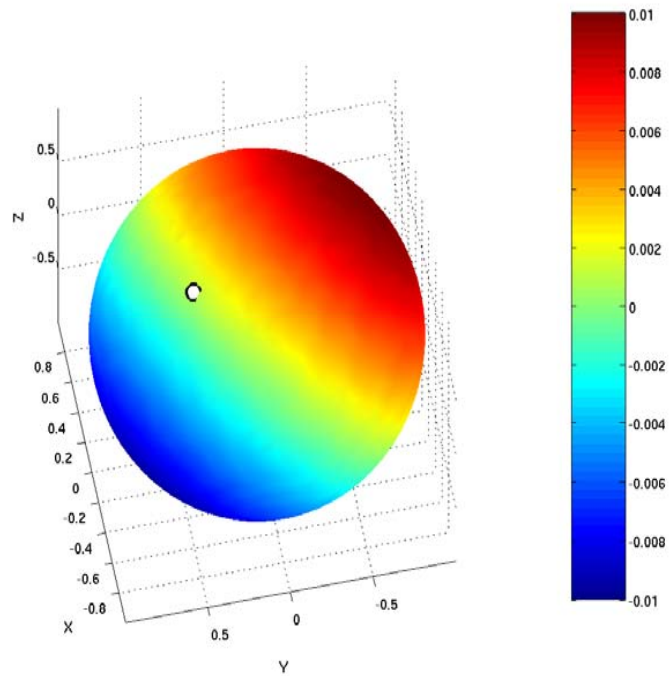
- Polarization changed
- Redefinition of parameters
- However, search over the space yields same max SNR value



All Sky Searches

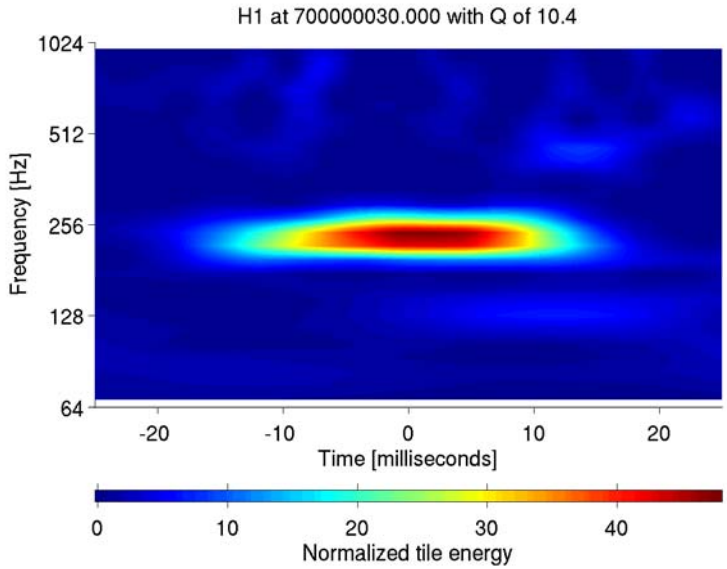
- Origin unknown
- Conduct searches over all sky



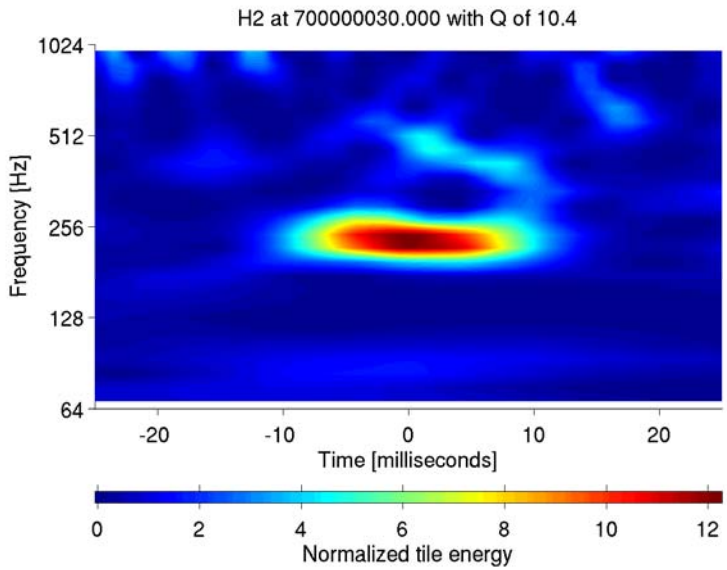


Consistency Checks

- Impossible to distinguish between GW and Glitches with two detectors (HL)
- H1 and H2 can be used for consistency checks
- Subtract out signal if true GW



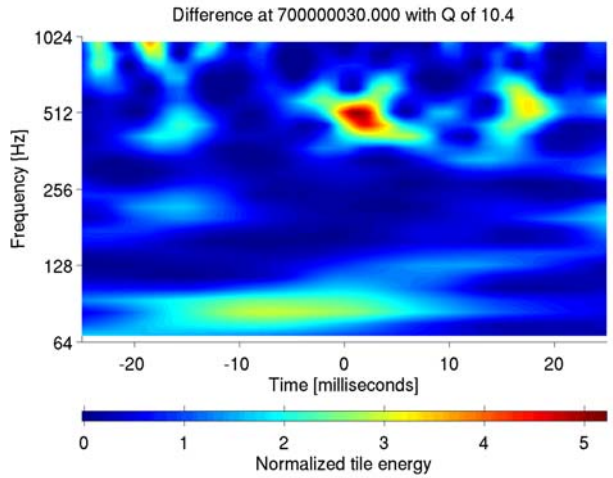
H1

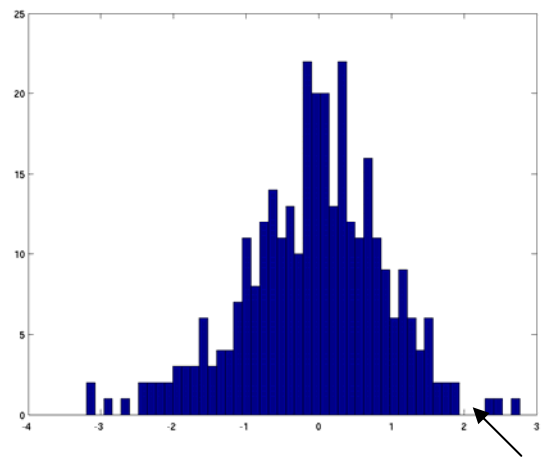


H2

Q Statistics, GW

- H1 H2 Consistency Check
- After subtraction Gaussian distribution expected in each component of coefficient
- Lilliefor test used
- Hypothesis test on whether GW or Glitch

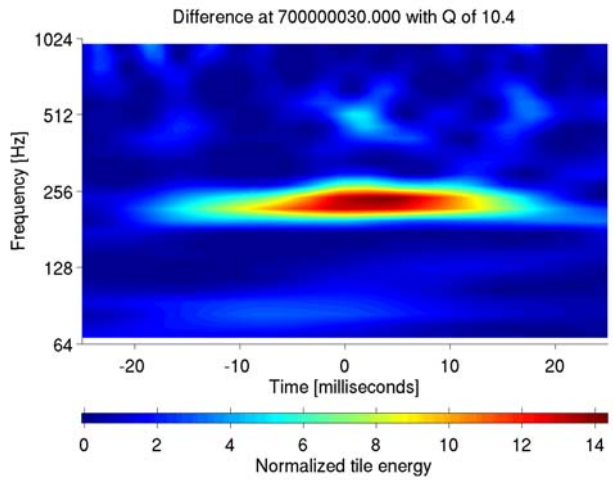


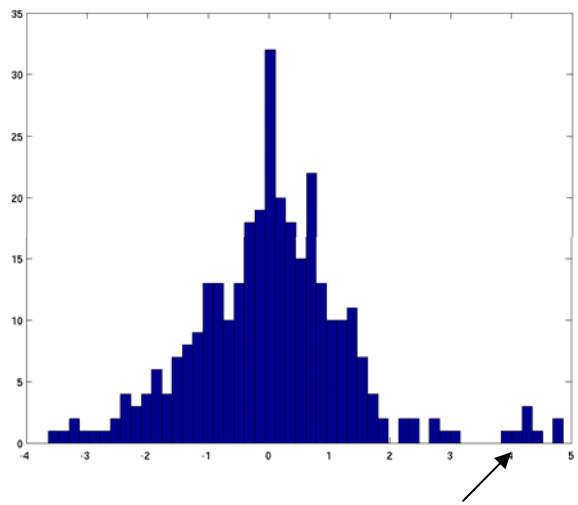


Max 3

Q Statistics, Glitch

- Simulated Glitch
- Subtraction not possible (complex coefficients)
- Reflected in the statistics of the difference transform





Conclusions

- Coherent Searches
- Coherent Sum: Improvement in SNR
- Consistency Checks using H1 and H2
- Future Work: Special class of waves Q Difference to distinguish between glitches and GW in HL network
- Run on real data