Search for Spinning Black Hole Binaries in Advanced LIGO: Parameter tuning of HACR

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ASIS session
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Overview

Goal: <u>Detection</u> of SBBH's in Time Frequency representation of Advanced LIGO data

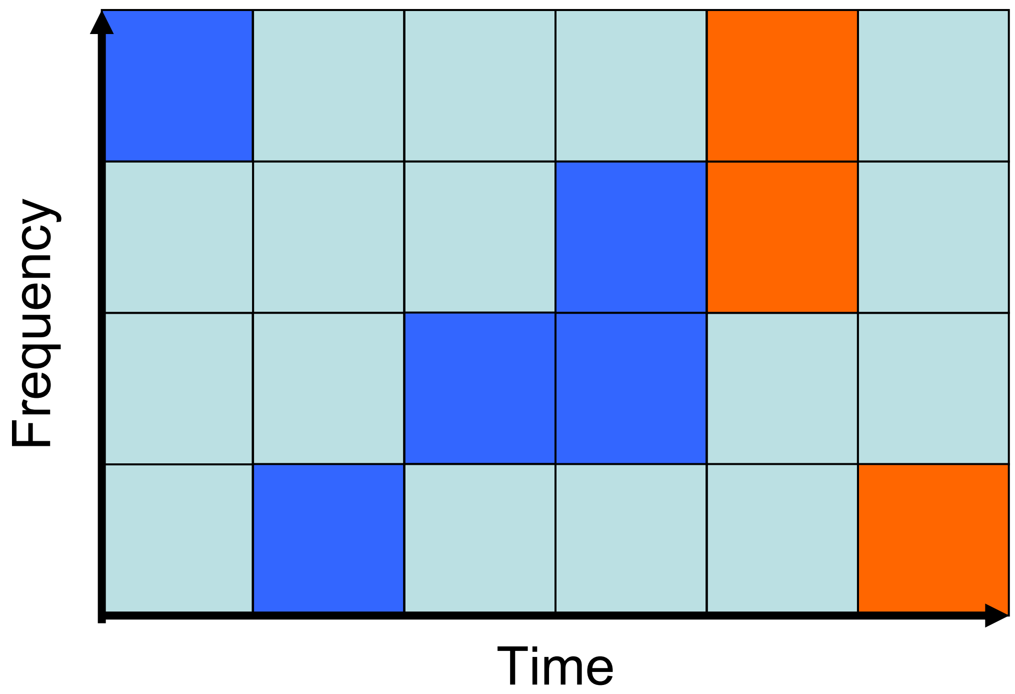
- What is HACR?
- Spinning Black Hole Binaries
- Tuning HACR in 2 steps
- Results
- Conclusions and Future Work

What is HACR?

- **H**ierarchical **A**lgorithm for **C**lusters and **R**idges written by R. Balasubramanian
- Time-frequency search
- Short bursts of excess power
- More robust than matched-filtering
- Implemented in GEO++ as HACRMon

How HACR works

1. Identify pixels with $P > \eta_{upper}$



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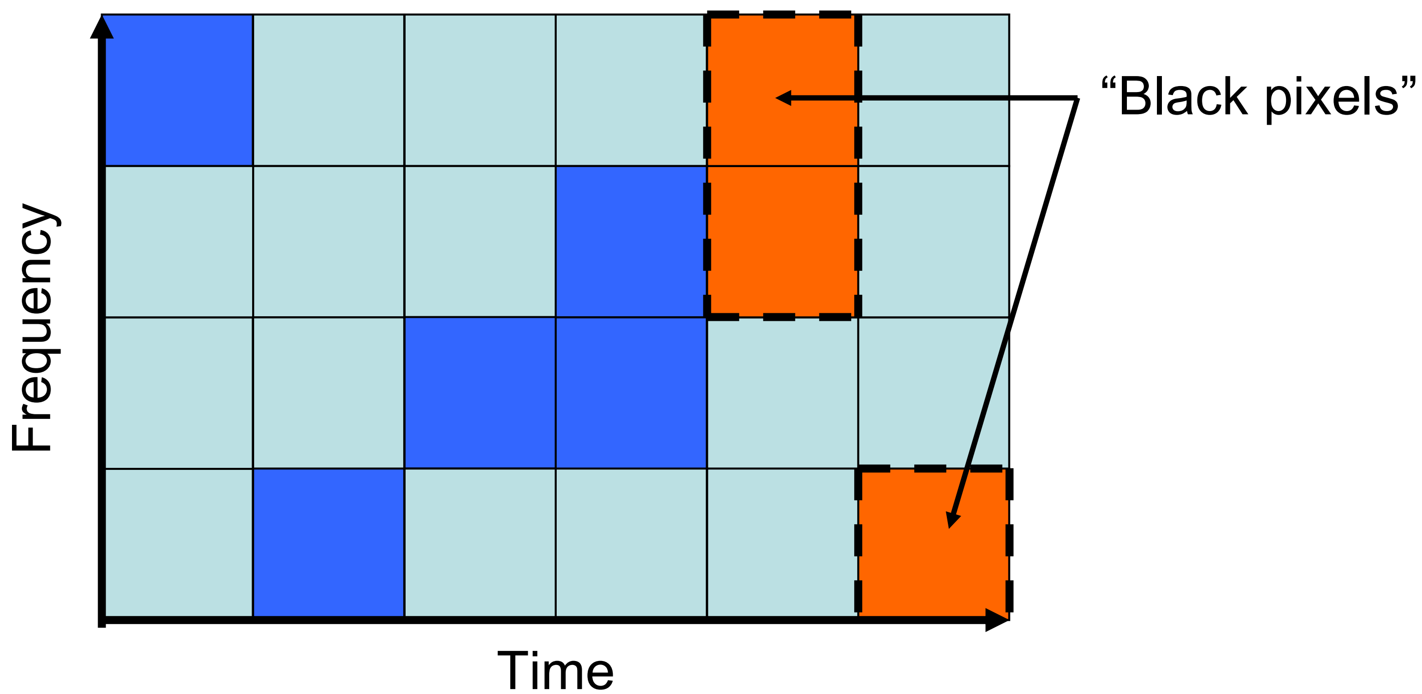
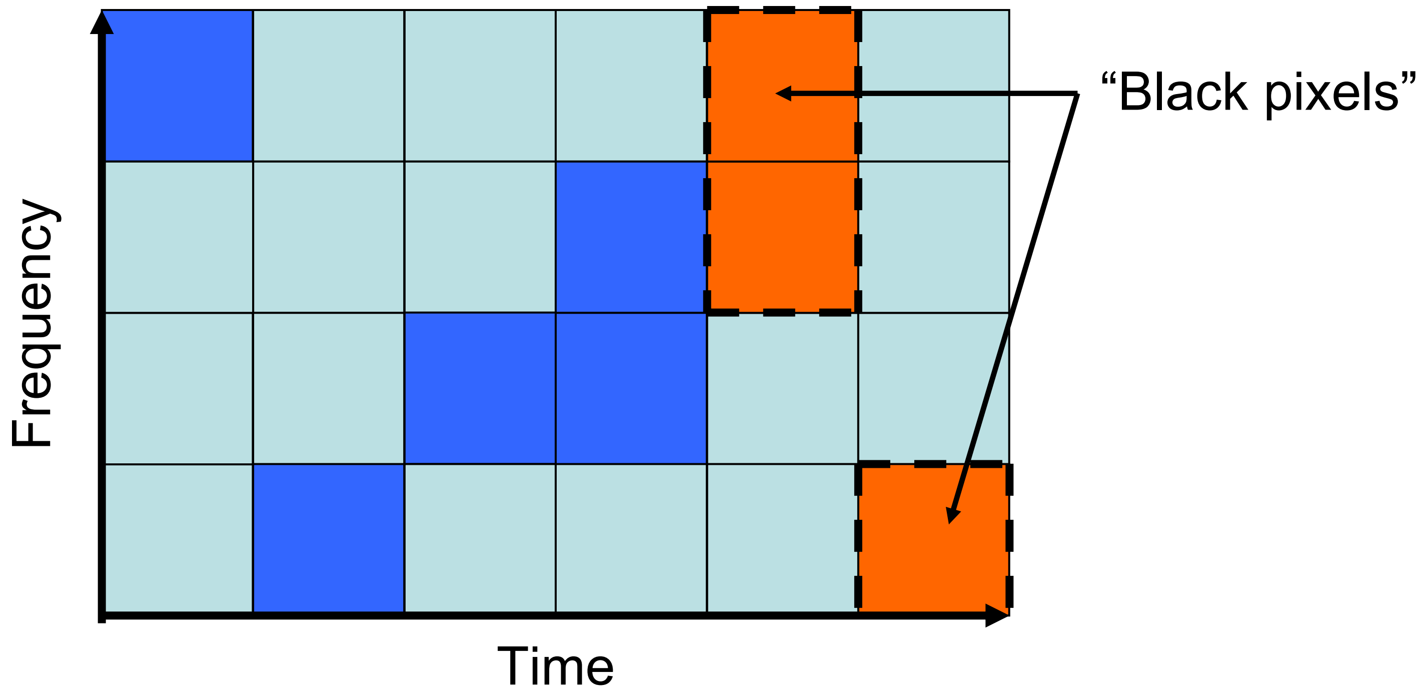


How HACR works

2. Identify neighbouring pixels with P > η_{lower}



How HACR works

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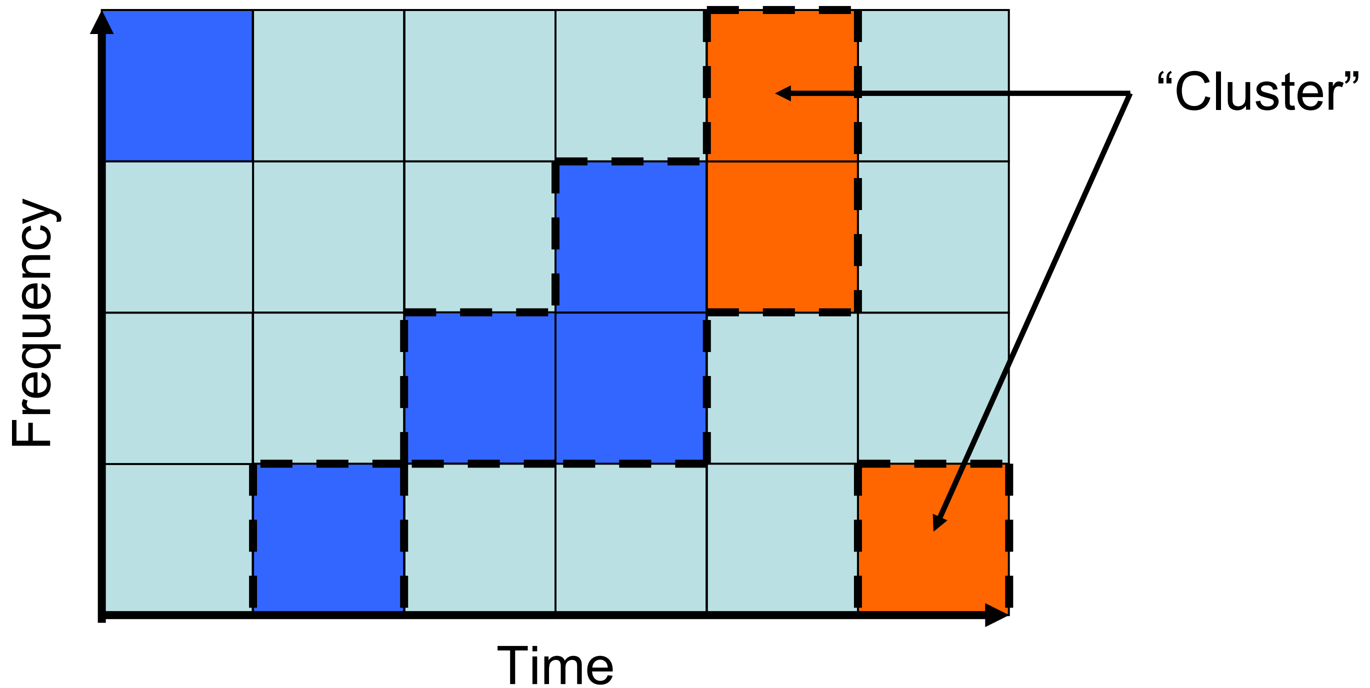
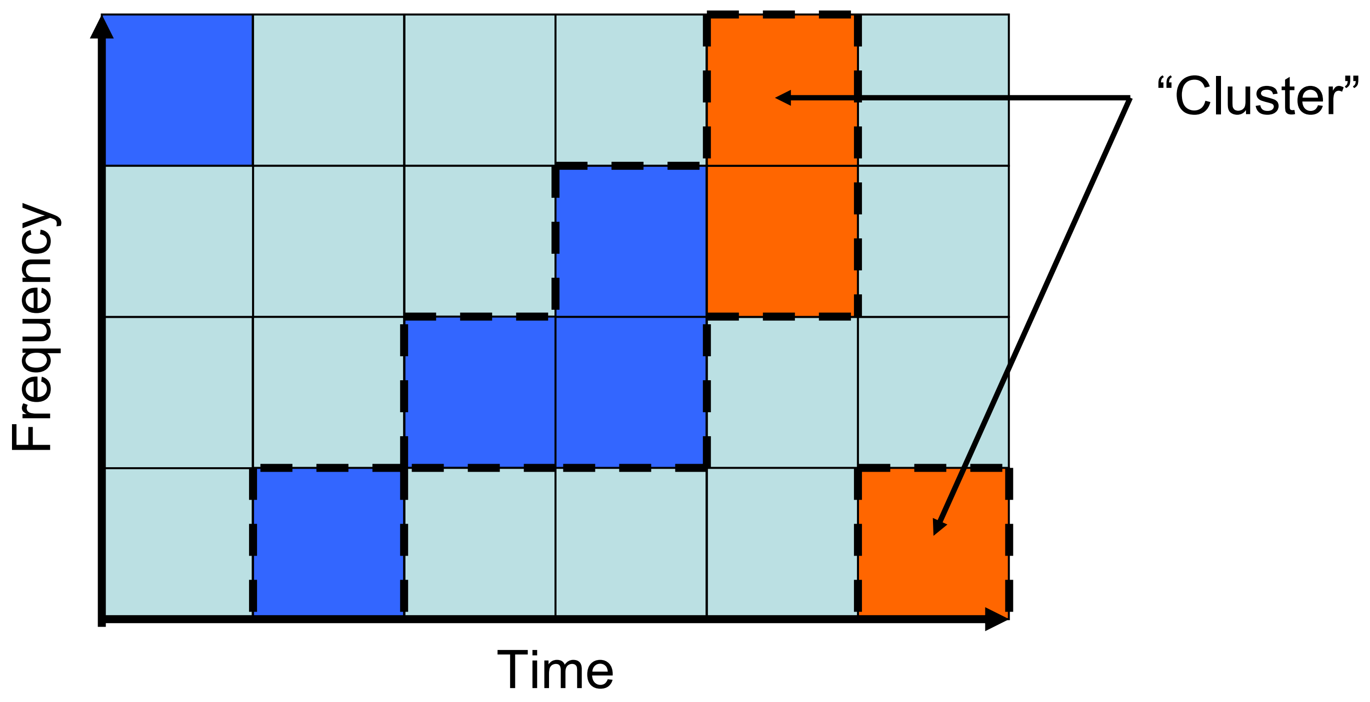


How HACR works

3. Identify clusters with $N_{pixels} > N_{threshold}$



How HACR works

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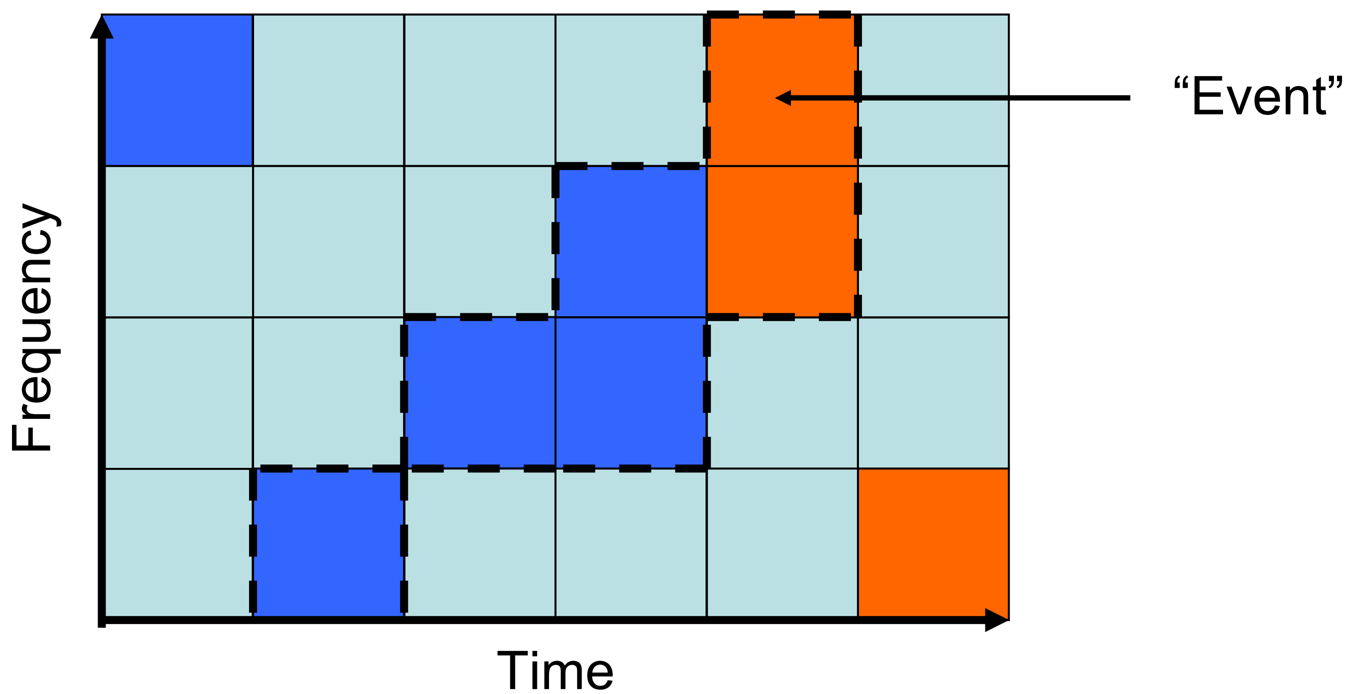
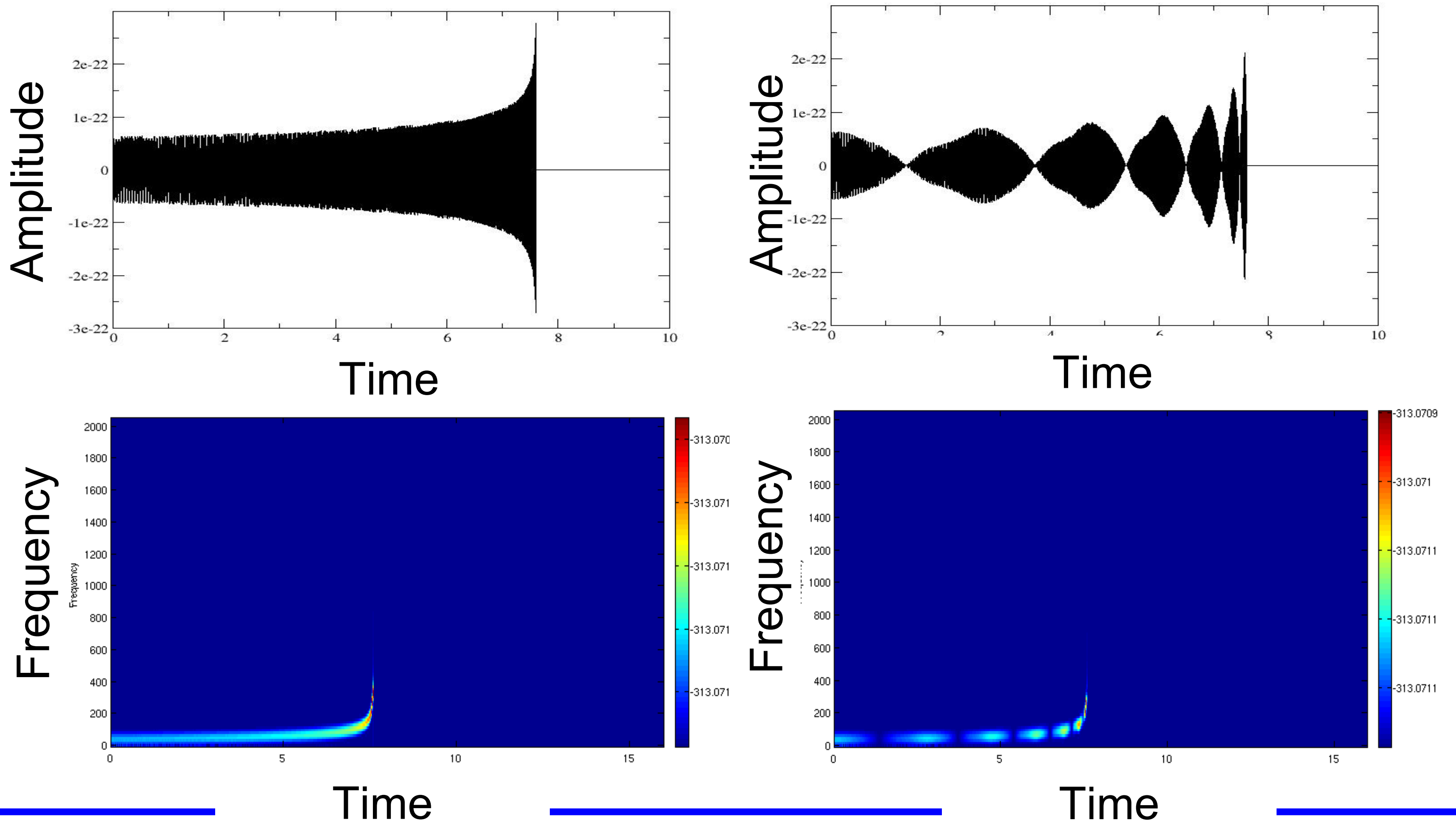


Spinning Black Hole Binaries

- Require 17 physical parameters to accurately describe waveform
- Spin-induced precession of orbital plane causes modulation of amplitude and phase
- Amplitude modulation causes of GW “archipelago” of clusters in TF map

Spinning Black Hole Binaries



Tuning HACR

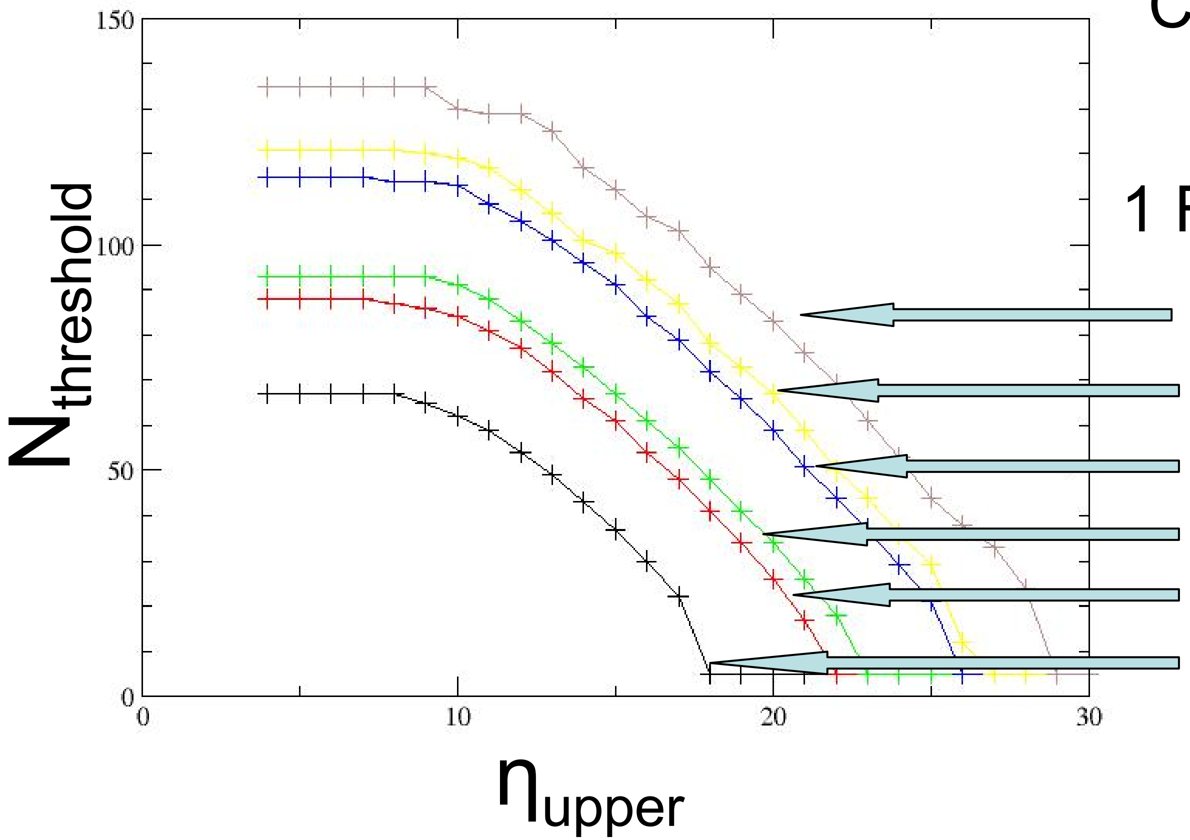
For a given false alarm rate maximise probability of detection

- Identify combinations of threshold parameters (η_{upper}, $N_{threshold}$) that produce a constant false alarm rate…
- … then for each combination of parameters measure probability of detection

False Alarm Analysis

- 100,000s of simulated Adv. LIGO data
- Analyse with low values of η_{upper} and $N_{threshold}$
- Store maximum-power and number of pixels for each found "event"
- For range of η_{upper} choose values of $N_{threshold}$ that give specific False Alarm rates

False Alarm Analysis



Contours of constant false alarm rate

1 False alarm per…

…hour (27.8 events)

…1000s (100 events)

…10 mins (166.7 events)

…100s (1000 events)

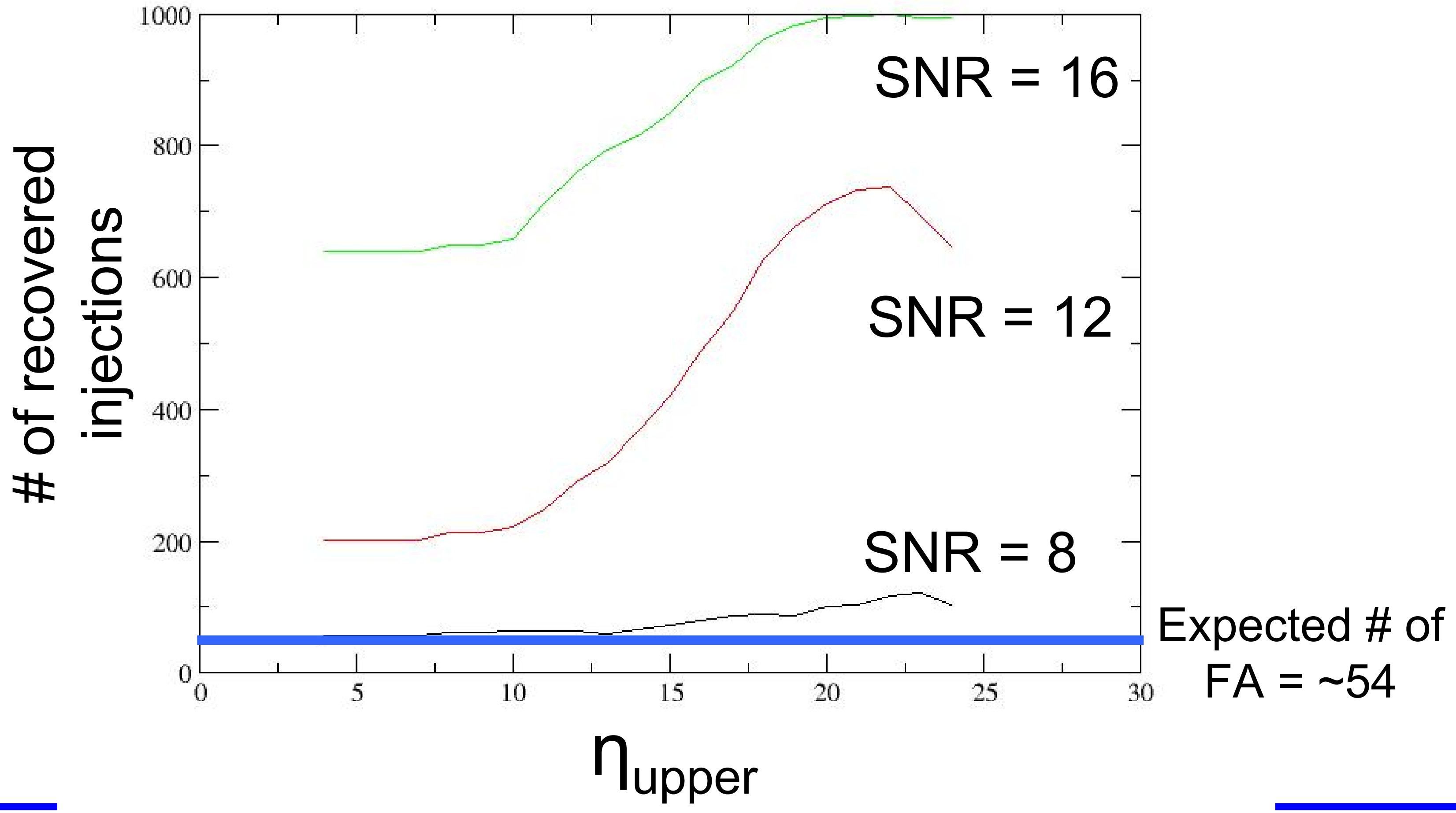
…min (1666.7 events)

…10s (10,000 events)

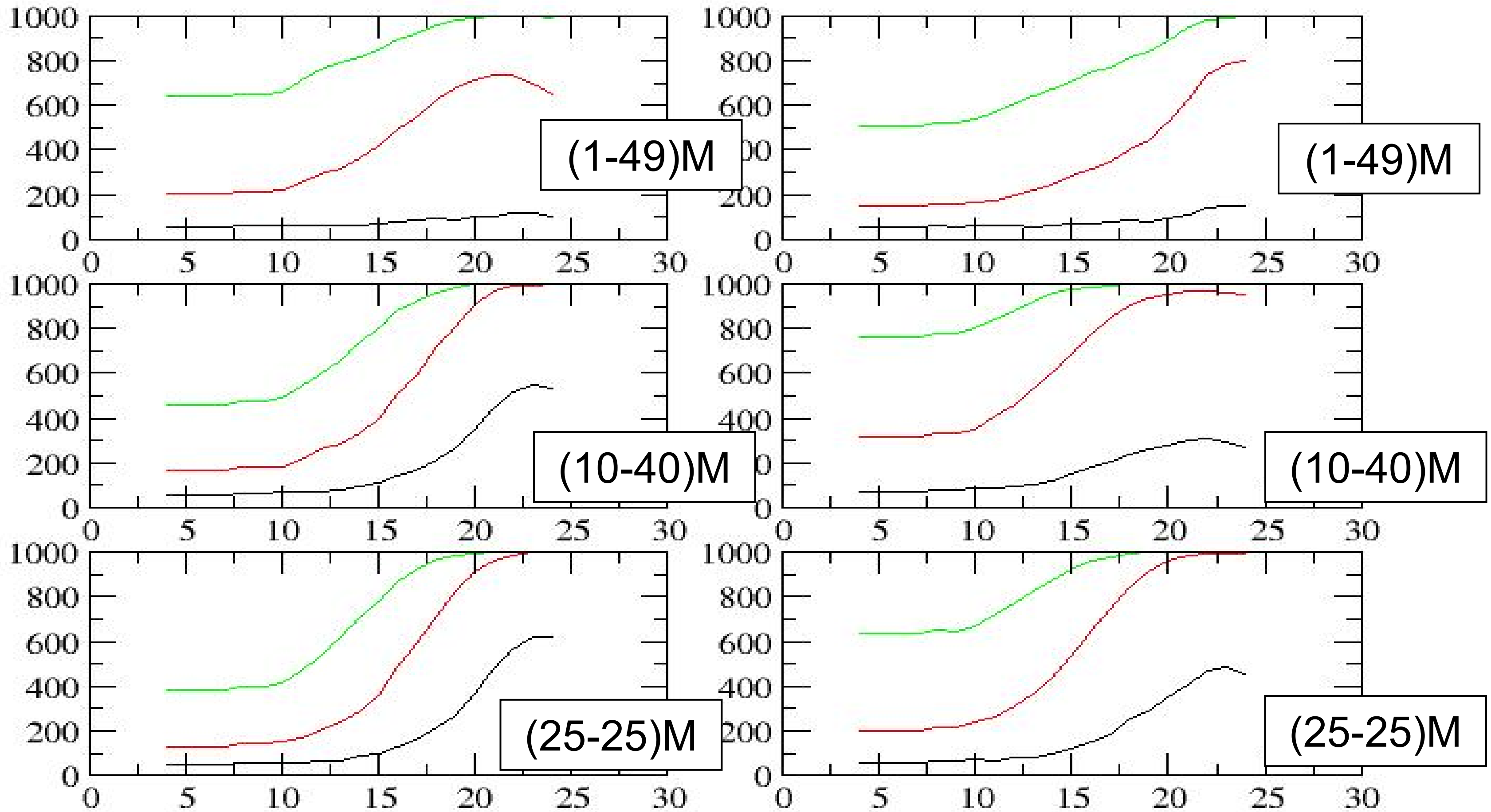
Injection of SBBH waveforms

- Physical waveforms
- (1-49), (10-40) and (25-25)M_{solar}
- 1000 injections each with SNR = 8,12,16
- Measure number of injections recovered for each combination of (η_{upper},$N_{threshold}$)

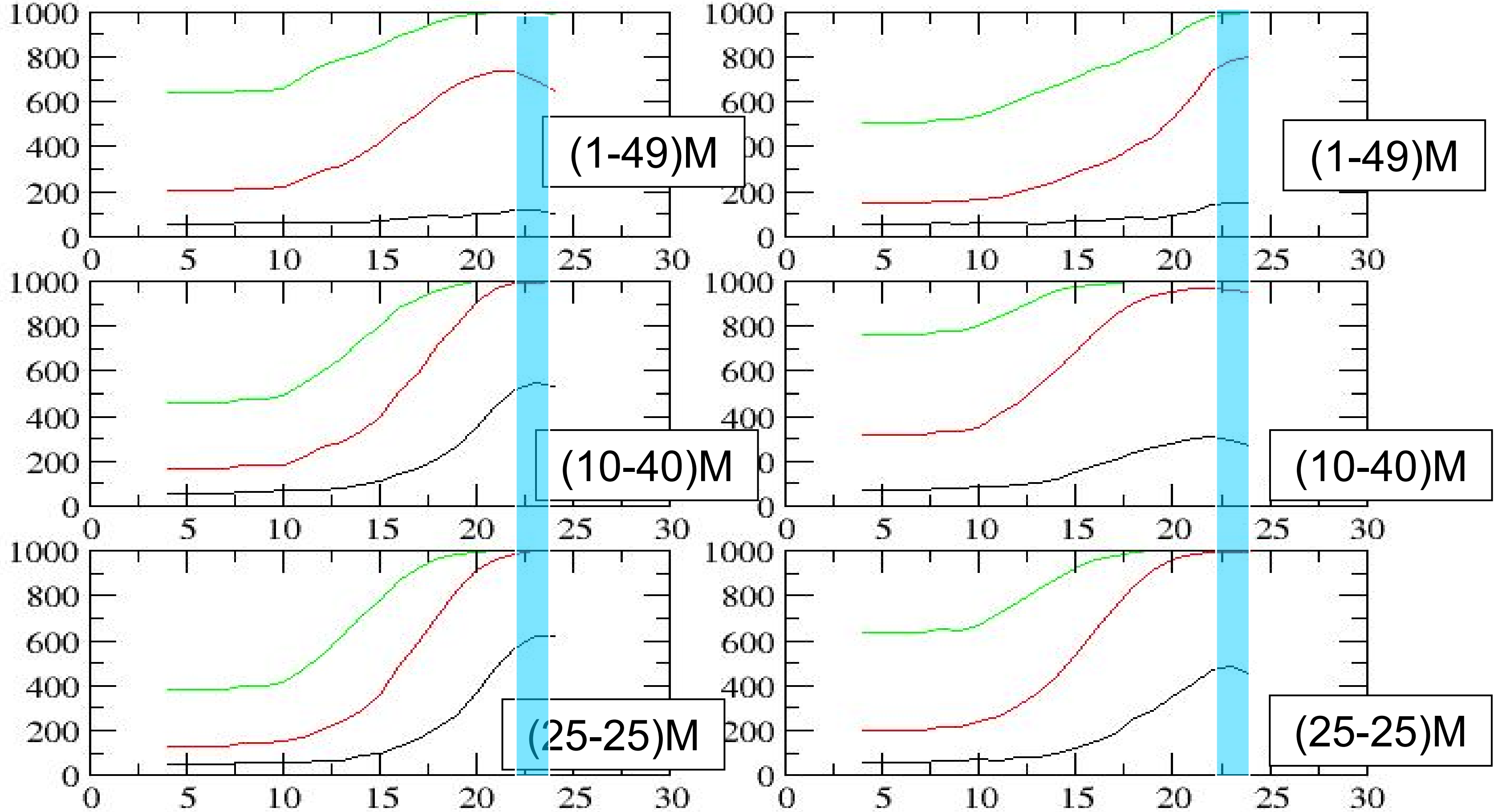
Results


1000
800
600
400
200
0
0
5
10
15
20
25
30
SNR = 16
SNR = 12
SNR = 8
Expected # of
FA = ~54
# of recovered
injections
η_{upper}

Small spin modulation | Large spin modulation



Small spin modulation　　Large spin modulation



$\eta_{upper} = 23$, $N_{threshold} = 50$

Conclusion and Future Work

- More injections and at various distances
- Power law pattern matching for potential event clusters
- Tune HACR for EMRI signals in LISA (with Jonathan Gair)