Innovations in the LSC's Binary Inspiral Search Pipeline

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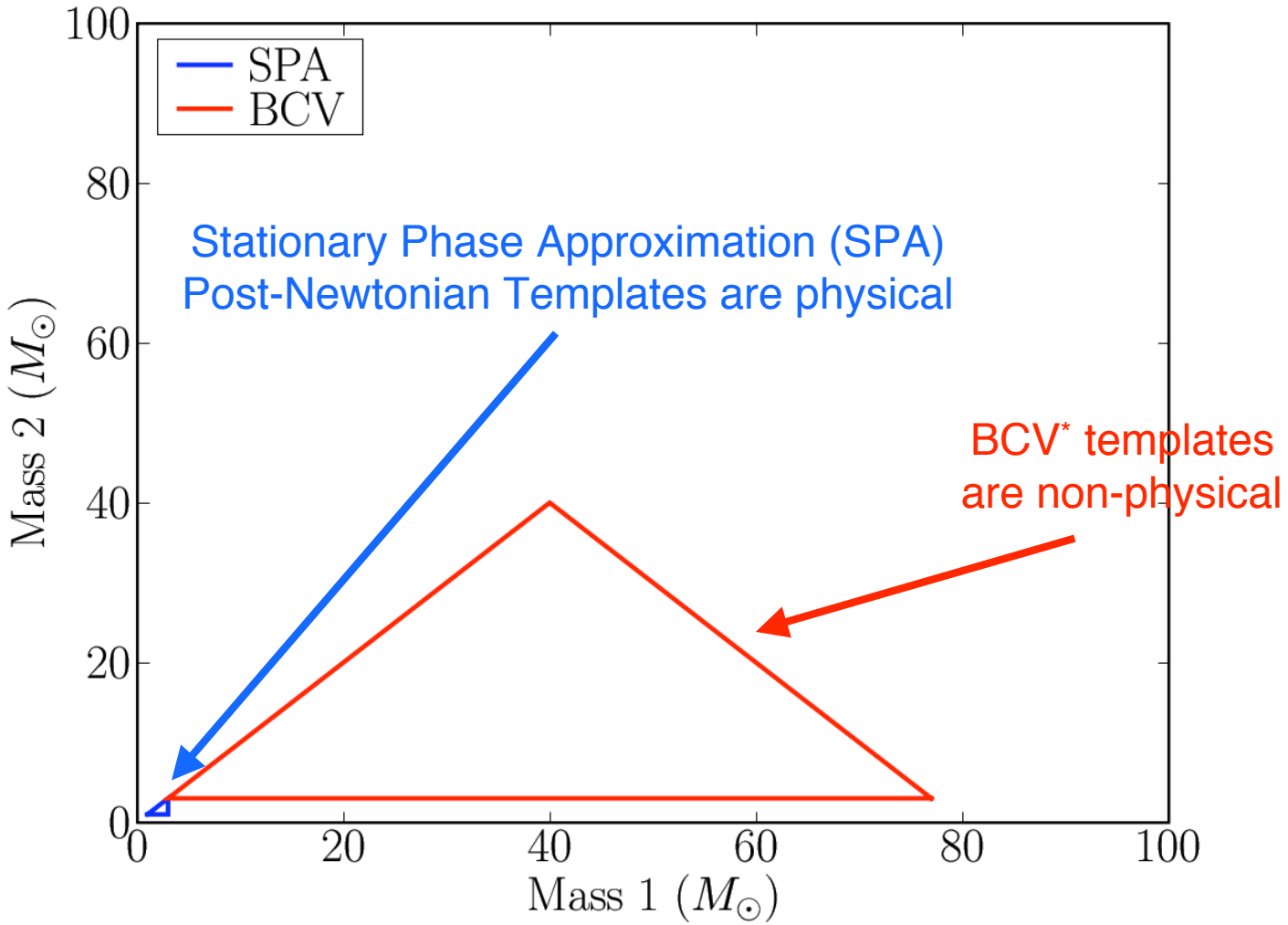
Introduction

- Differences in the template bank between the S3 & S4 Searches and the S5 Search
  - » Investigations that led to the differences
- Estimated Background Trigger Investigations
- Change in clustering / coincidence algorithm

S3 & S4 Searches



*A. Buonanno, Y. Chen, and M. Vallisneri, Phys. Rev. D **67**, 024016 (2003).

Template Bank Investigations

- Investigation of SPA templates in up to 35 $M_{\odot}$
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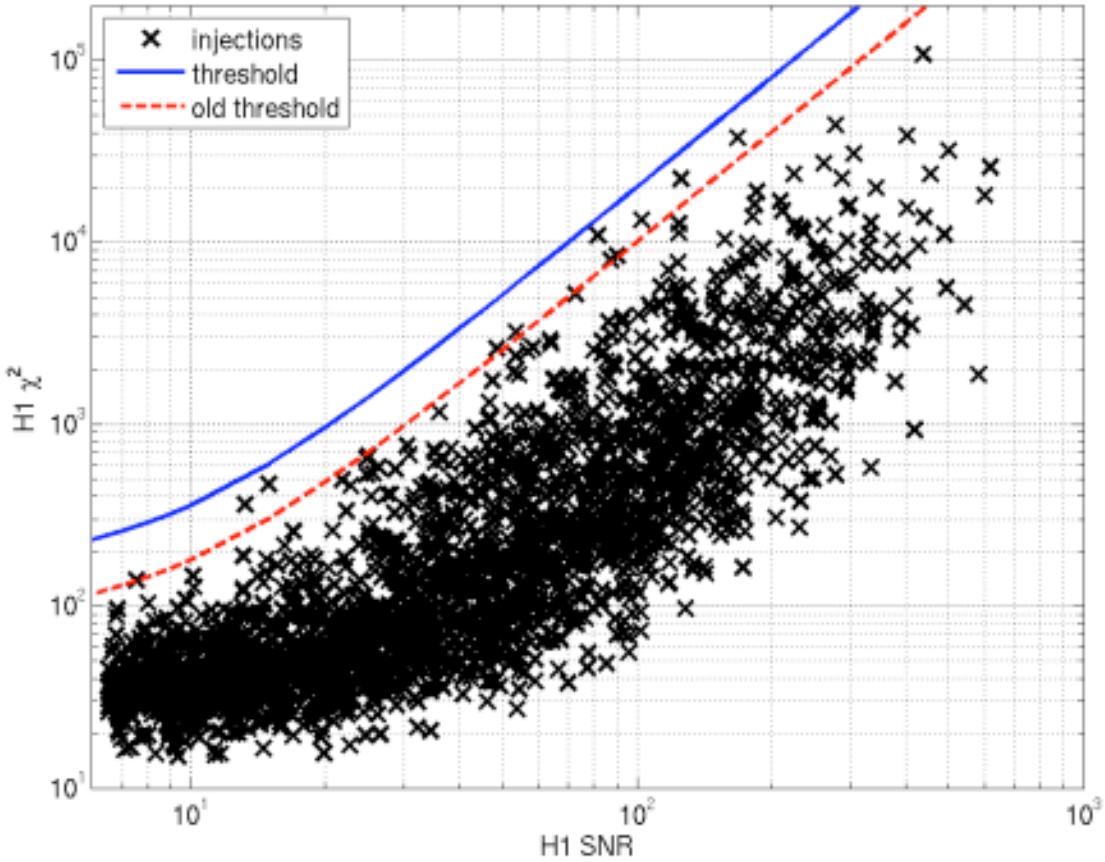
  - » Investigation done to study searching for spinning injections with non-spinning templates

Injections with Spin

- Coalescence of spinning systems can be detected with non-spinning templates
  - » Loosen veto χ^2 threshold



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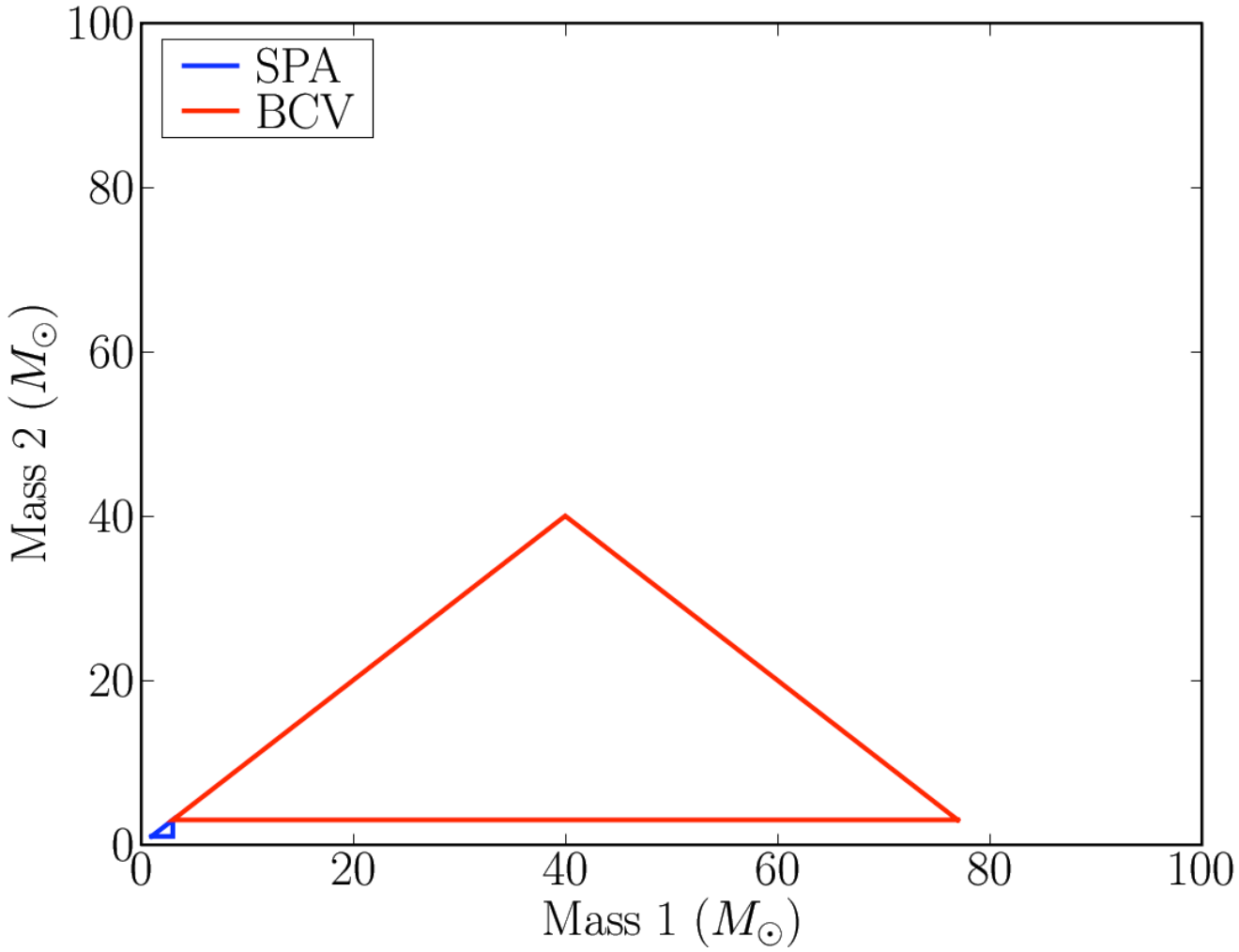
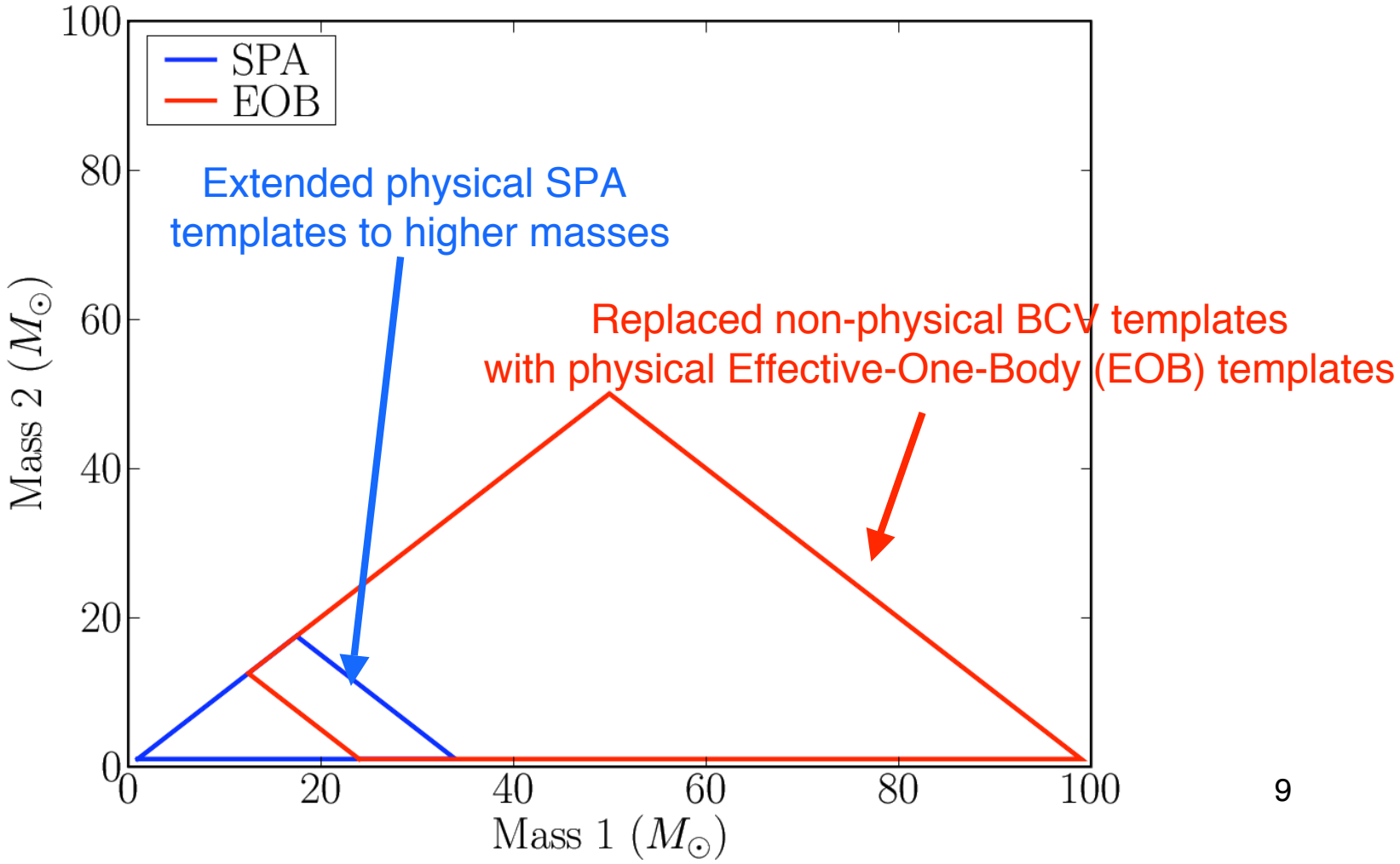
- Searching for non-spinning binaries where physical systems will have some amount of spin
  - » Investigation done to study searching for spinning injections with non-spinning templates
- Searching for quasi-circular binaries even though real binaries will have residual eccentricity
  - » Investigation done to study effects of eccentricity on our detection efficiency

S3 & S4 Searches



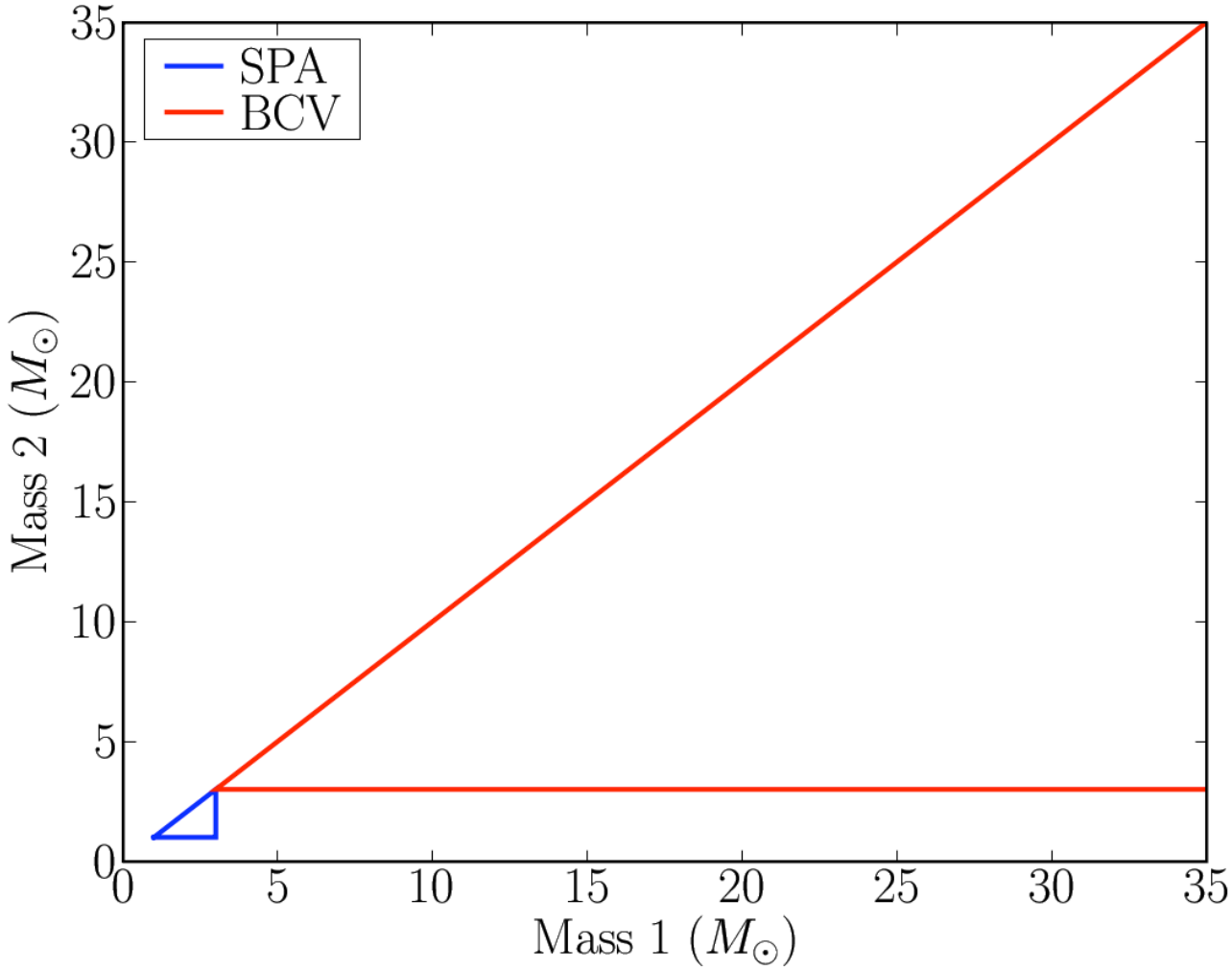
S5 Searches


SPA
EOB
Extended physical SPA
templates to higher masses
Replaced non-physical BCV templates
with physical Effective-One-Body (EOB) templates
Mass 2 ($M_\odot$)
Mass 1 ($M_\odot$)
0
20
40
60
80
100

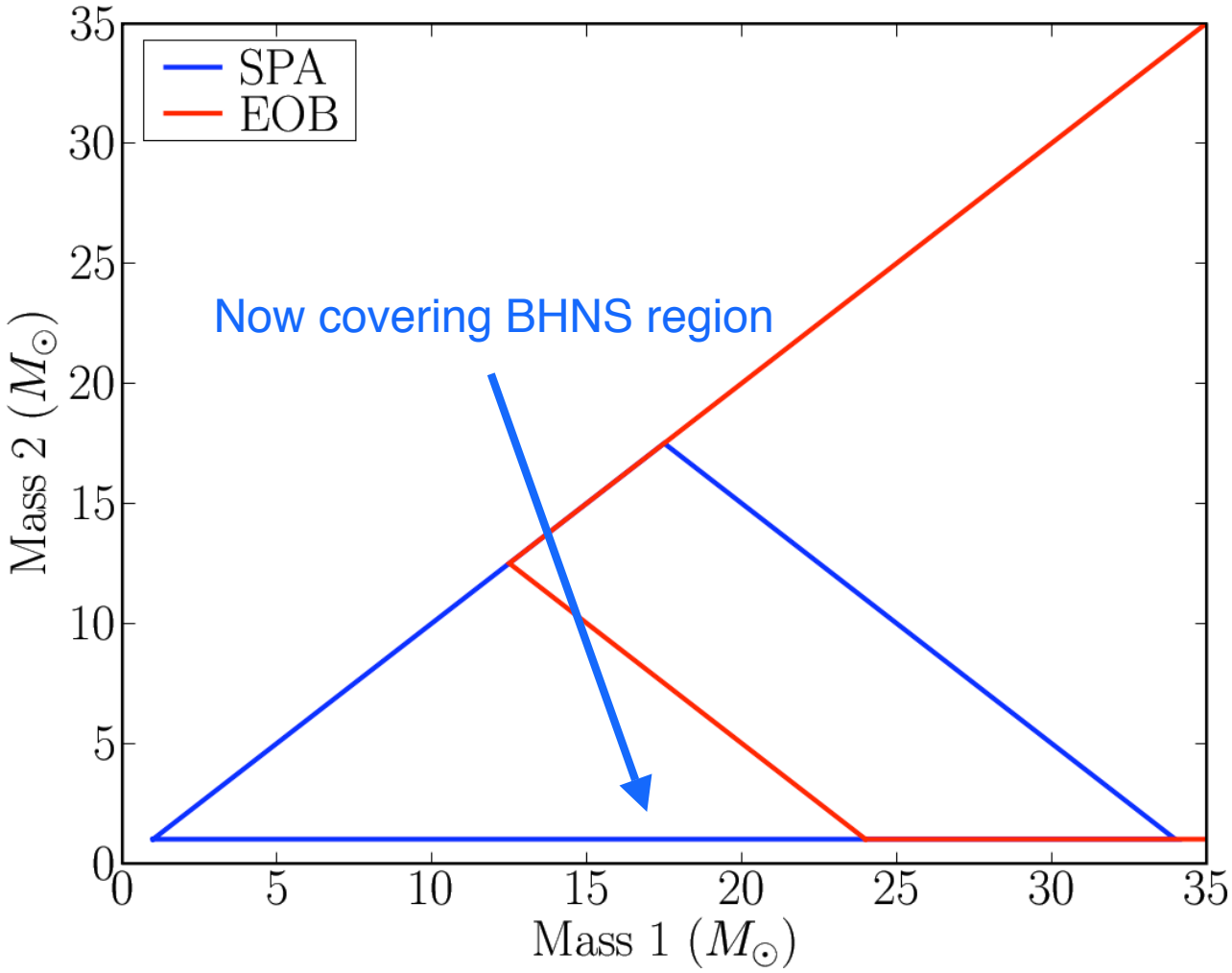
S5 Searches

- Low Mass Region
  - » Use (0.0, 2.0) PN in (amplitude, phase) SPA templates
  - » Cutoff frequency at Innermost Stable Circular Orbit
  - » Component masses from 1 - 34 $M_{\odot}$
  - » Maximum total mass of 35 $M_{\odot}$
- High Mass Region
  - » Use (0.0, 2.0) PN in (amplitude, phase) EOB Time Domain templates
  - » Cutoff frequency at Light Ring
  - » Component masses from 1 - 99 $M_{\odot}$
  - » Total mass of 25 - 100 $M_{\odot}$

Low Mass Region
S3 & S4 Searches

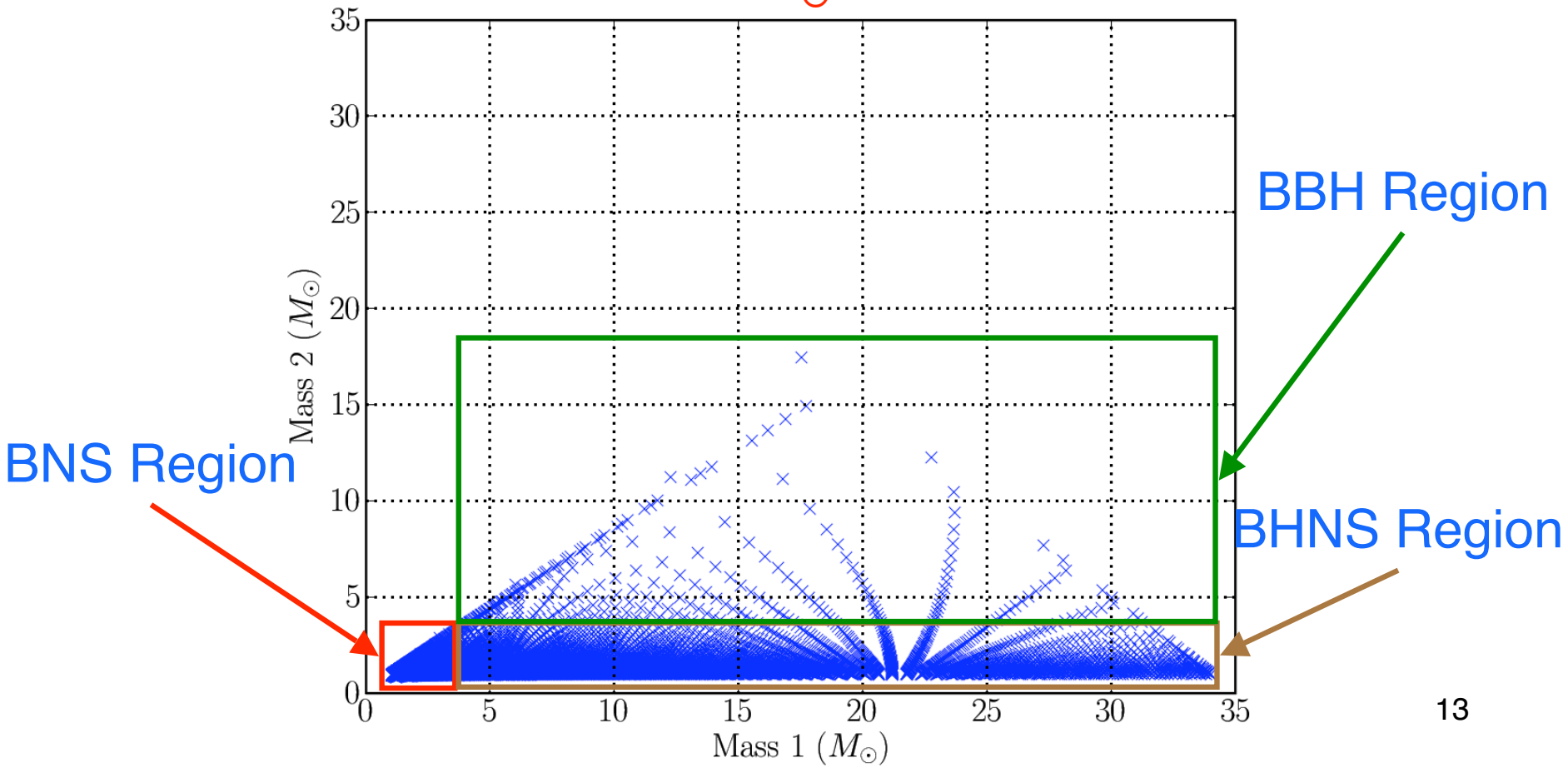


Low Mass Region
S5 Search



S5 SPA Template Bank

- Component masses from 1 - 34 $M_\odot$
- Maximum total mass of 35 $M_\odot$



Background Investigations

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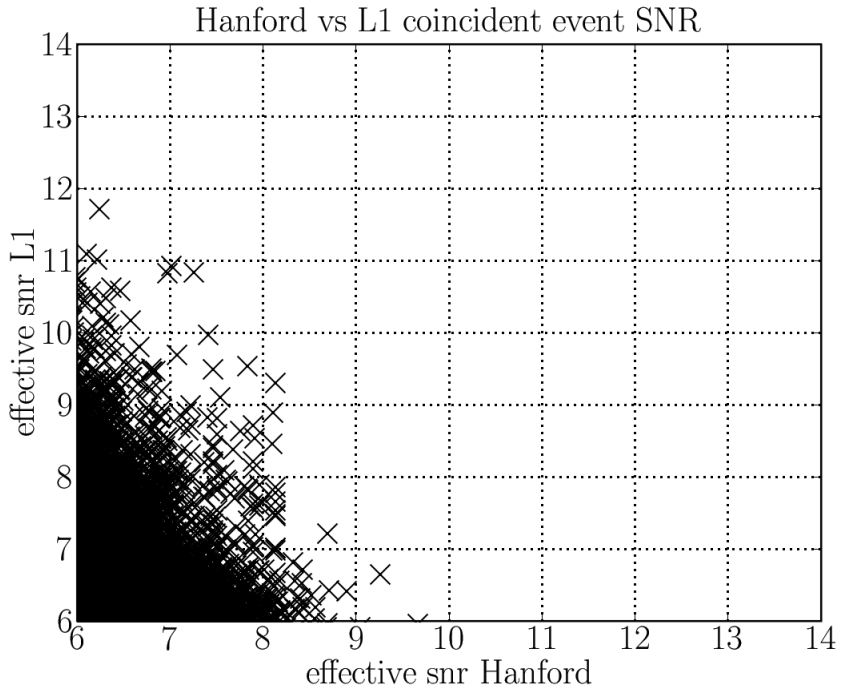
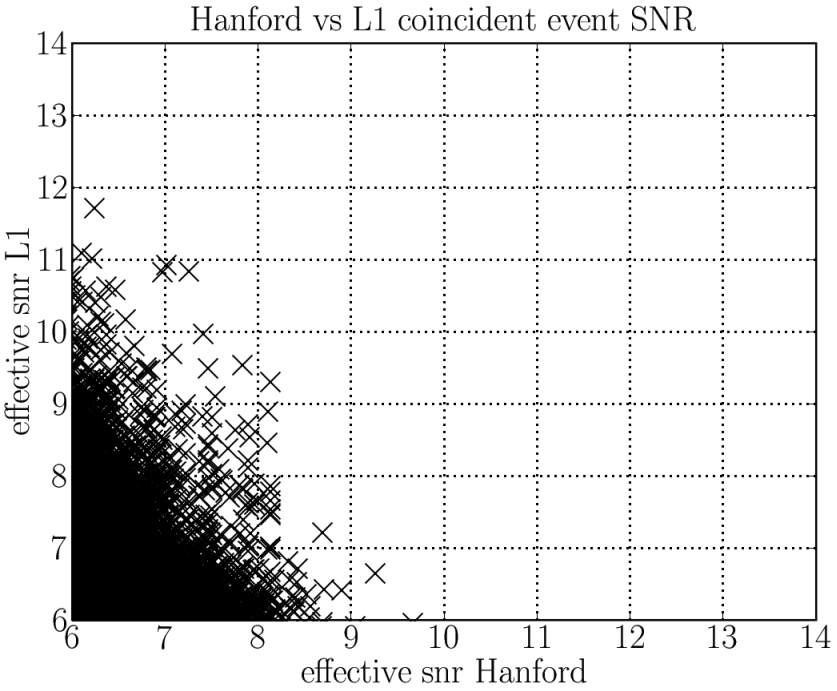
Estimated Background Triggers

Full Mass Region



Full Mass Region

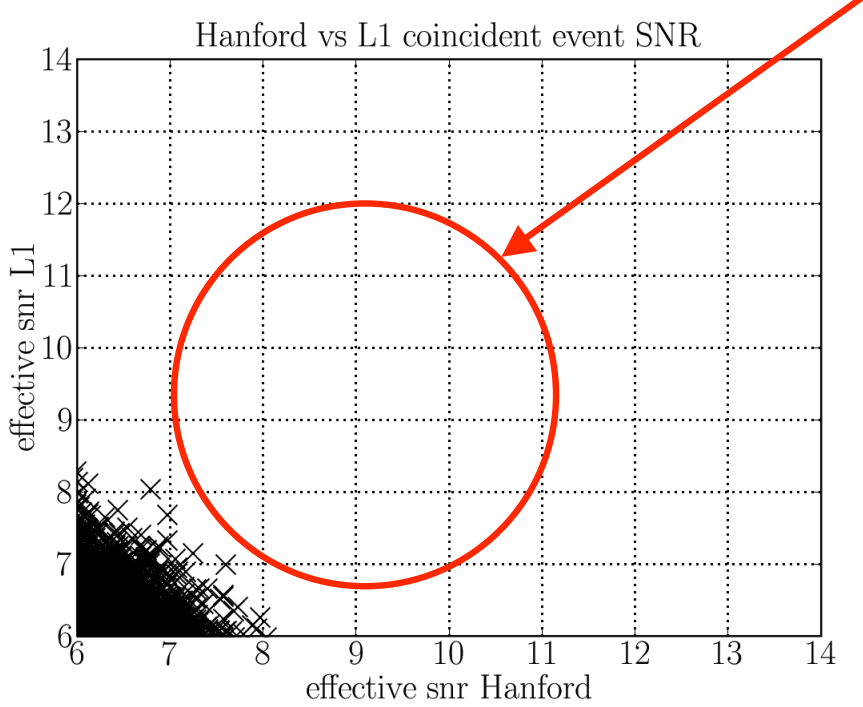


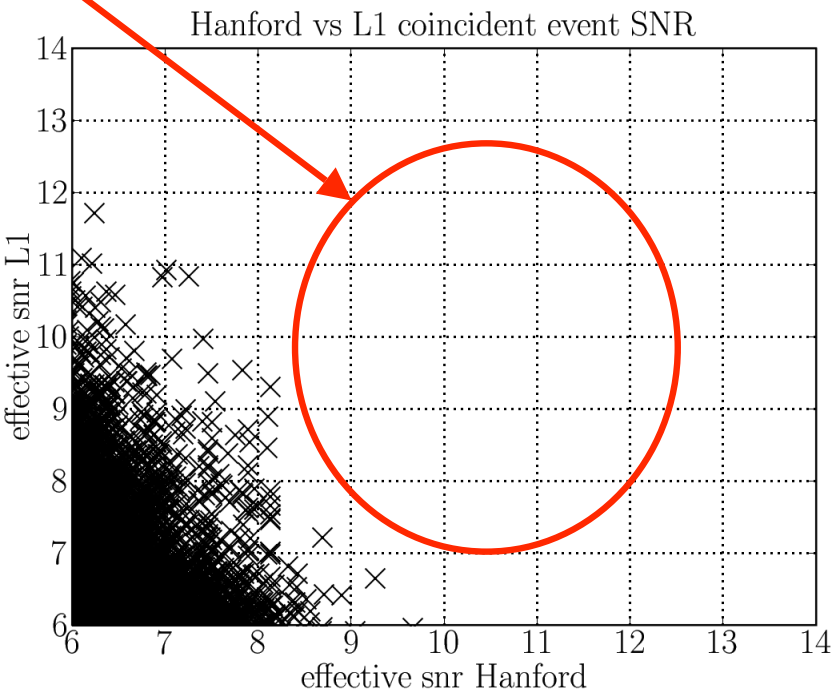
Estimated Background Triggers

BNS Mass Region

No Background!

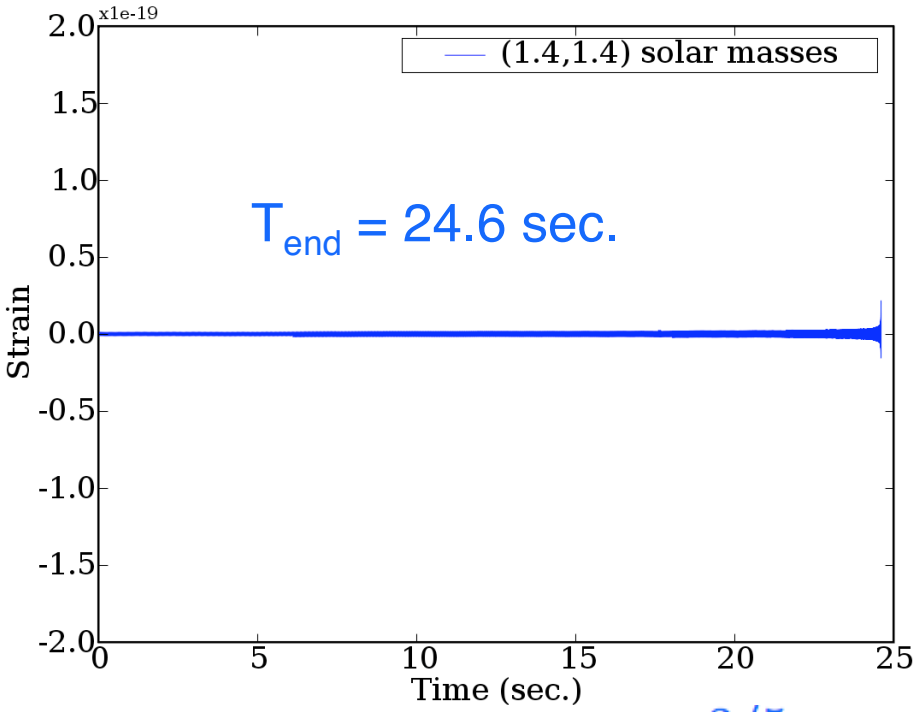
BBH Mass Region





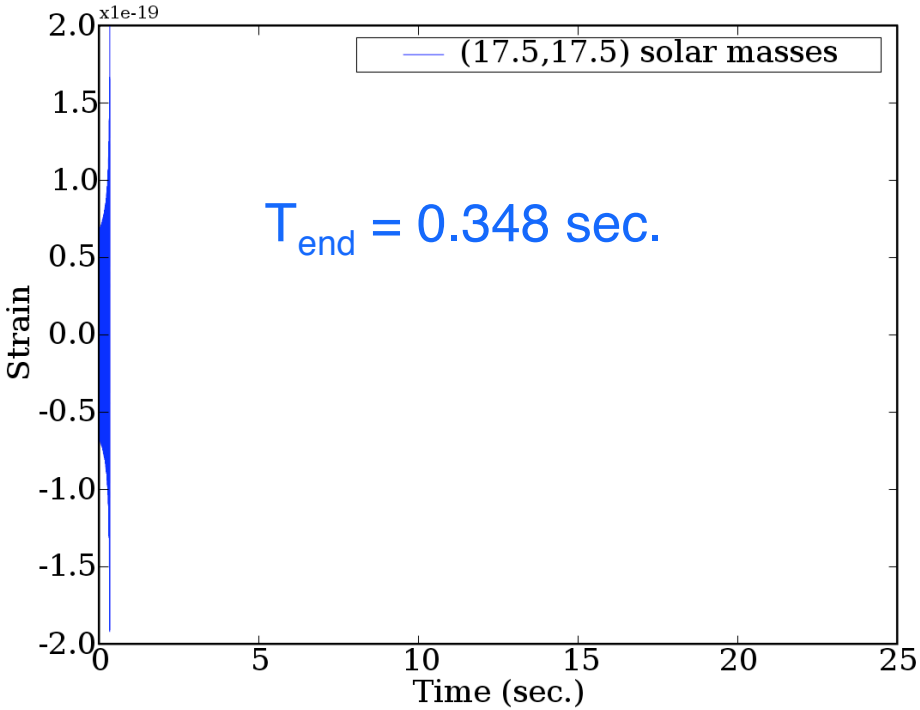
Template Length

BNS Mass Region



T_{end} = 24.6 sec.

BBH Mass Region



T_{end} = 0.348 sec.

$$M_{chirp} = \eta^{3/5} M_{total} \qquad \eta = \frac{m_1 m_2}{(m_1+m_2)^2}$$

Background Investigations

- Estimate background using non-physical time-slide coincidences
- Different background distributions for different portions of the mass region
  - » Higher mass region has shorter templates and higher effective SNR estimated background triggers
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  - » Group triggers by where software injections are found in template space

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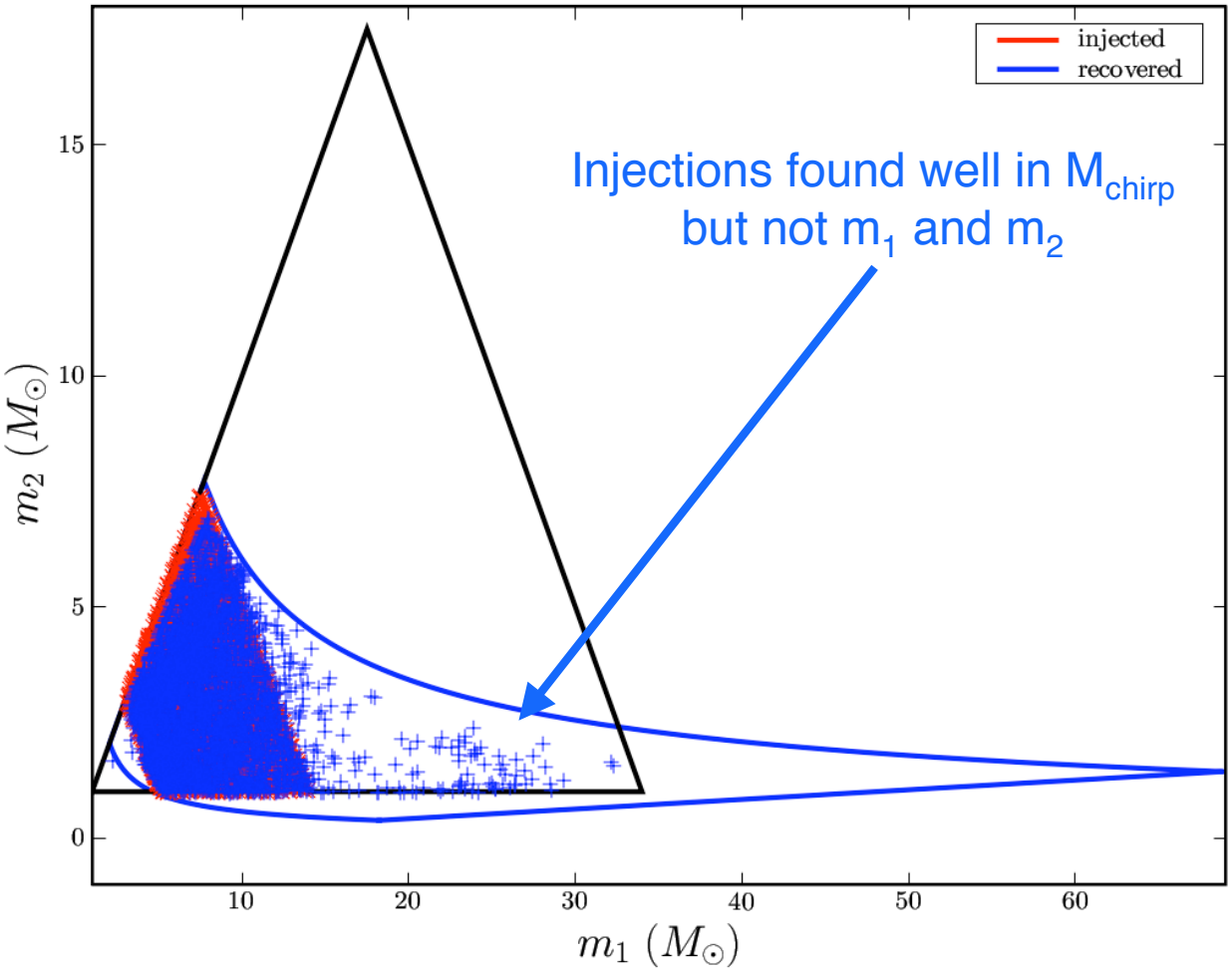

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  - » Group triggers by where software injections are found in template space
- Investigation of excess of H1H2L1 triggers at low SNRs
  - » Time-slides done by sliding H1, H2 and L1 separately
  - » Sliding H1 and H2 together against L1 gives correct background estimation
    - – Known excess of H1H2 triggers compared to expected H1H2 background

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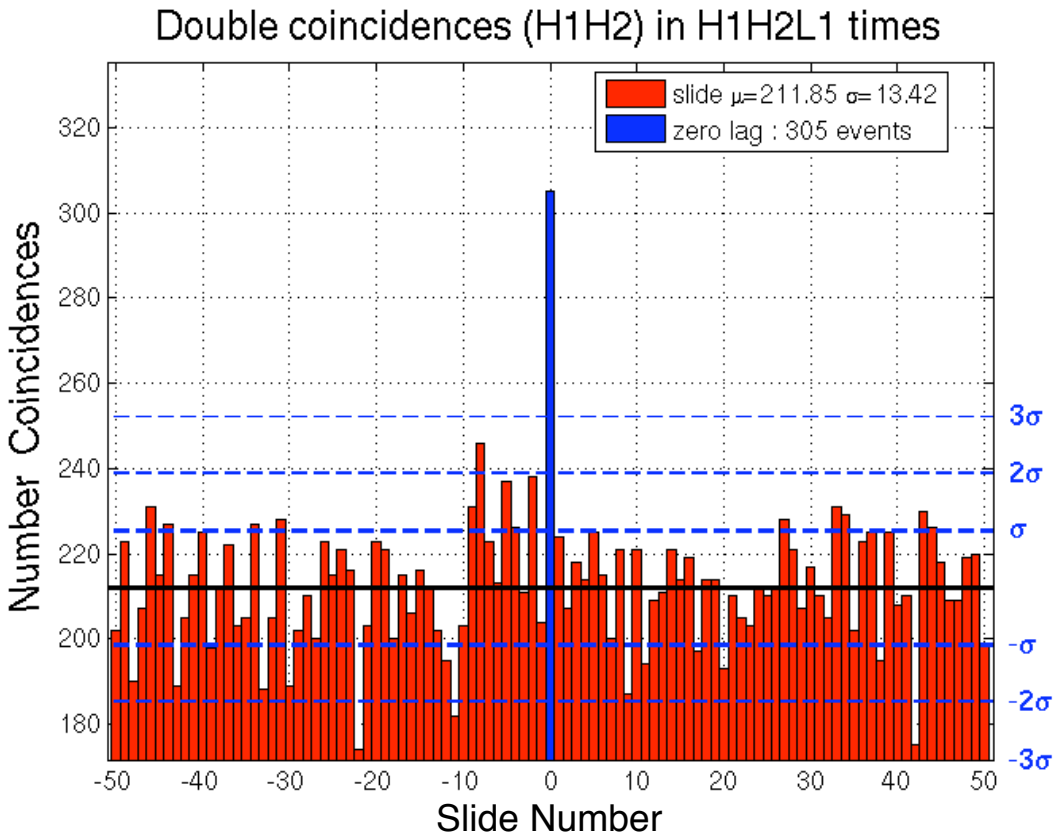
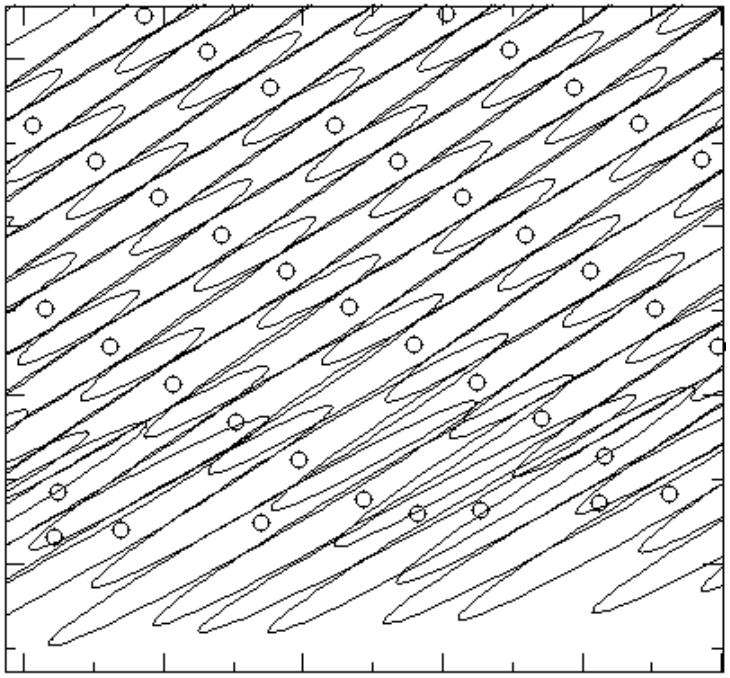


- Future investigation of H1H2 estimated background
  - » Slide H1 and H2 by a few hundred milliseconds instead of tens of seconds
  - » Supporting plot from S4 BBH Search (gr-qc/0704.3368)

Clustering / Coincidence Calculation

- Previous searches used clustering and coincidence algorithms that were fixed over the mass space
  - » Used windows on the values of M_{chirp}, η, $t_{coalescence}$
- New coincidence based on metric used for template placement
  - » Variable across mass space
  - » Error ellipsoids in M_{chirp}, η, and $t_{coalescence}$
  - » Coincidence step in pipeline called e-thinca



The End

Search Pipeline Overview

- Search for binaries with components between 1 and 35 solar masses
  - » Maximum total mass of 35 solar masses
  - » Use data from three LIGO detectors
- Matched filter search using second order post-Newtonian templates
  - » Generates first stage triggers
- Apply time, mass, (amplitude) coincidence
  - » Ensure trigger is present in at least 2 LIGO detectors
- Apply signal based vetoes e.g. χ^2
  - » Vetoes are expensive: applying after first coincidence saves CPU
- Re-apply coincidence to get candidate triggers
- Construct coherent inspiral statistic
- Follow up event candidates remaining at end of pipeline