The Search for Low Mass Compact Binary Coalescences in LIGO's S5 Data.

David McKechan, Cardiff University

For the LIGO Scientific Collaboration

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The LIGO S5 & Virgo VSR1 Science Runs

- LIGO S5 science run, November 2005 – October 2007:
  - Detectors operating at design sensitivity.
  - 3 detectors at 2 sites, Hanford, WA and Livingston, LA.

- Virgo VSR1 science run coincided with the last 5 months of S5.
  - Based in Cascina, Italy.
  - Similar sensitivity to Hanford 2km.

The Search for Low Mass Compact Binary Coalescences

- The search is divided in to 3 separate searches:

  - S5 1st Year Search
    - *Paper available (arXiv:0901.0302).*
    - *Set new constraints on the rate upper limits.*
    - *0.40 years coincident and non-vetoed data.*

    DONE

  - S5 12-18 Month Search
    - *The data after the first year, but before VSR1.*
    - *Less data, but increased sensitivity.*
    - *0.25 years coincident and non-vetoed data.*

    NEW

  - Joint S5-VSR1
    - *The first joint search between LIGO and Virgo.*

    RESULTS SOON

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The S5 12-18 Low Mass Search Overview

- Essentially identical to the S5 1st Year Search:

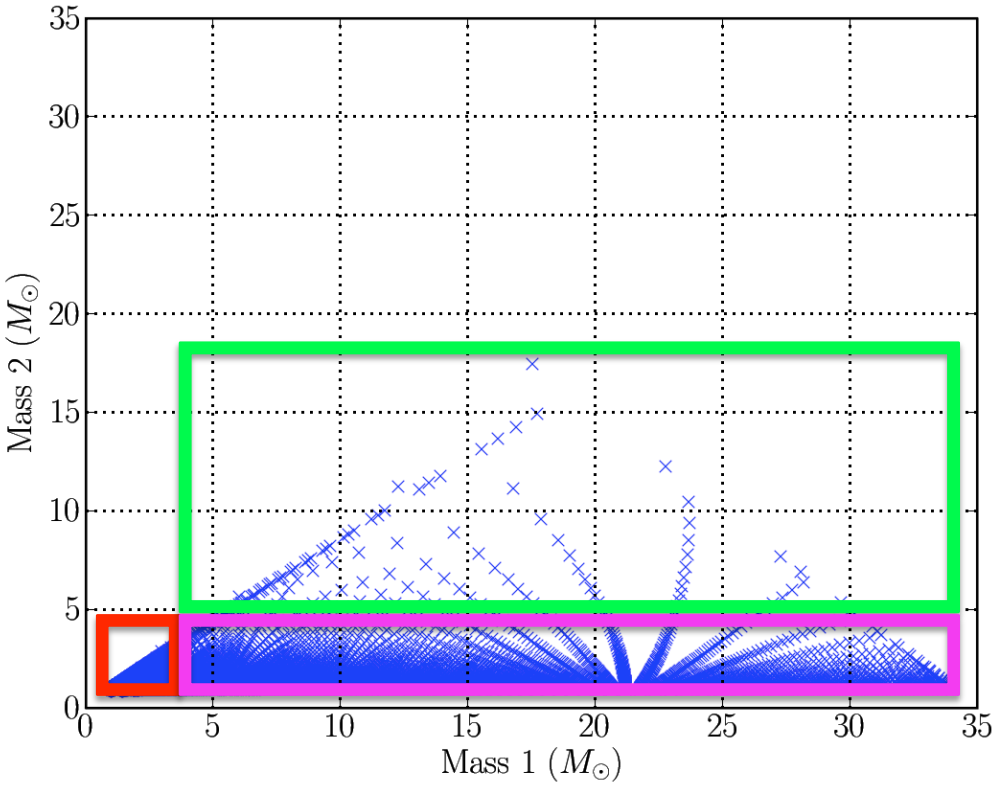
  - We search for binary systems consisting of Neutron Stars and/or Black holes with a total mass of between 2-35$M_\odot$, with a minimum component mass of 1$M_\odot$.
    - *Separate high mass search with 25$M_\odot$ < M_{TOTAL} < 100 $M_\odot$ - (Evan's Talk).*

  - The template bank consists of 2nd order Post-Newtonian SPA waveforms.

BNS

BBH

BHNS



The S5 12-18 Low Mass Search Overview

- Differences…
  - The search was divided in to 7 “months” for separate analysis.
    - This allows background estimation to account for variation in detector behavior over the course of the search.
    - This is also a step towards future automated low latency analyses.
  - Each month is searched individually for possible gravitational wave candidates.
- Then…
  - Upper limits on the rates of compact binary coalescences are set combining the results from each of the months and using the rate limits from the S5 1st Year search as *prior* information.

Background Estimation & Detection Statistic

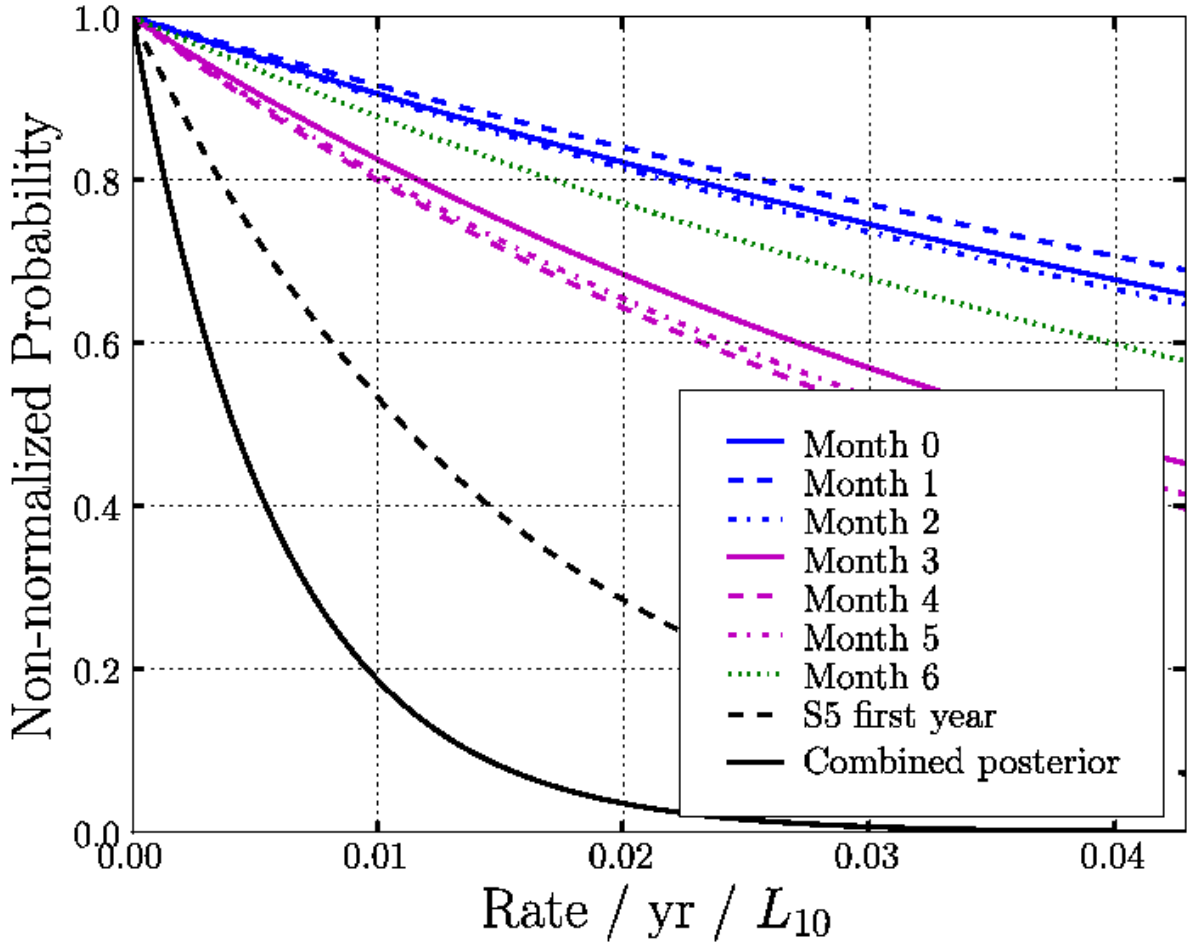
- *Background Estimation…*
  - We *time-slide* the data between the two LIGO sites and run the standard pipeline.
  - This means that any coincident events between the sites cannot be from a true signal.
  - After performing 100 time-slides we have measured a False Alarm Rate (FAR), for different types of triggers and IFO times
    - *BNS and BBH have different FARs.*
    - *Different detector combinations e.g., H1L1 and H1H2L1 have different FARs.*
- *Detection Statistic…*
  - Using the FAR allows us to compare foreground triggers from different categories.
    - *We find it convenient to use the Inverse False Alarm Rate (or IFAR) as our Detection Statistic.*

Results!

- *NO Detection Candidates!* ☹
  - The loudest trigger had an IFAR of 0.16 years.
  - We therefore set rate upper limits, first individually on each month with a uniform prior before combining each month with the posterior rate limits from the S5 1st year low mass search.
  - Upper limits are a combination of how much of the Universe we were sensitive to and for how long we searched.
  - Upper limit rates are quoted in units of L_{10}^{-1} yr^{-1}. L_{10} is 10^{10} times the blue light solar luminosity.
  - The Milky Way contains ~ 1.7 L_{10}.

Rate Upper Limits – BNS *(Non-Spinning)*

- BNS rate *90%* confidence = 1.4 x 10^{-2} L_{10}^{-1} yr^{-1} - *a factor of 3 lower than S5 1st Year*.



Rate Upper Limits *(Non-Spinning)*

- BNS rate *90%* confidence = $1.4 \times 10^{-2}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - *Where BNS is (1.35, 1.35)* $M_{\odot}$.

- BBH rate *90%* confidence = $7.3 \times 10^{-4}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - *Where BBH is (5.0, 5.0)* $M_{\odot}$.

- BHNS rate *90%* confidence = $3.6 \times 10^{-3}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - *Where BHNS is (5.0, 1.35)* $M_{\odot}$.

Rate Upper Limits Compared with Astrophysical Expected Rates

- *Our Results…*
  - BNS rate *90%* confidence = $1.4 \times 10^{-2}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BBH rate *90%* confidence = $7.3 \times 10^{-4}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BHNS rate *90%* confidence = $3.6 \times 10^{-3}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.

- *Astrophysical OPTIMISTIC Rates…*
  - BNS rate = $5 \times 10^{-4}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BBH rate = $6 \times 10^{-5}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BHNS rate = $6 \times 10^{-5}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.

  ~ 1-2 orders of magnitude.

- *Astrophysical BEST ESTIMATE Rates…*
  - BNS rate = $5 \times 10^{-5}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BBH rate = $4 \times 10^{-7}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.
  - BHNS rate = $2 \times 10^{-6}\, L_{10}^{-1}\ \mathrm{yr}^{-1}$.

  ~ 3 orders of magnitude.

Future

- *2009…*
  - *The results of the LIGO-Virgo S5 low mass search to be obtained.*
  - *LIGO S6 run, with improved sensitivity.*
  - *Virgo VSR2, with improved sensitivity.*

- *2014…*
  - *Advanced LIGO begins operation.*
  - *Will see 1000 times the volume of the Universe compared to Initial LIGO!*

Thanks for Listening

- *Any Questions… ?*