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

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Syracuse University

On behalf of the LIGO Scientific Collaboration

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SUOS CULTORES SCIENTIA CORONAT

FOUNDED AD 1870

LIGO VIRGO

- LIGO
  - ⇨4k and 2k at Hanford, WA
  - ⇨4k at Livingston, LA

- Virgo
  - ⇨3k at Cascina, Italy

The LIGO S5 & Virgo VSR1 Science Runs

- LIGO S5 Science run
  - ⇨ November 2005 - October 2007
- Virgo VSR1 science run coincided with last 5 months
- Multiple searches done
  - ⇨ Compact Binary Coalescence (CBC)
    - Low Mass
      - ⇨ $2M_\odot \leq M_{TOTAL} \leq 35M_\odot$ (with $M_{COMP} \geq 1M_\odot$)
    - High Mass
      - ⇨ $25M_\odot \leq M_{TOTAL} \leq 100M_\odot$
    - GRB triggered
  - ⇨ Others: Burst, Stochastic, Continuous Wave

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CBC Low Mass Searches

- *S5 1st year:* November 2005 - November 2006
  - ⇨ 0.40 years of coincident data
  - ⇨ Paper available
    - PRD 79, 122001 (2009)
- *S5 12-18 Month Search:* November 2006 - May 2007
  - ⇨ 0.25 years of coincident data
  - ⇨ Increased sensitivity
  - ⇨ Paper now available (arXiv:0905.3710)
- *Joint S5-VSR1:* May 2007 - October 2008
  - ⇨ Paper in the works

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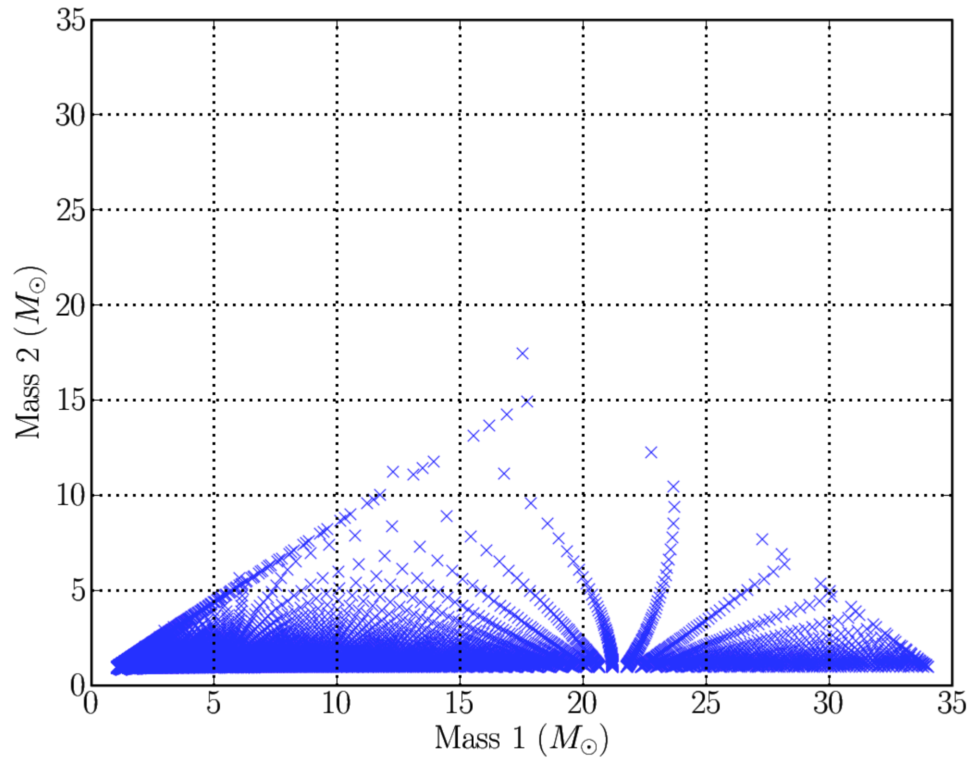
12-18 Month Overview

- Similar to S5 1st Year Search
- Match filter with 2nd Order PN SPA template bank



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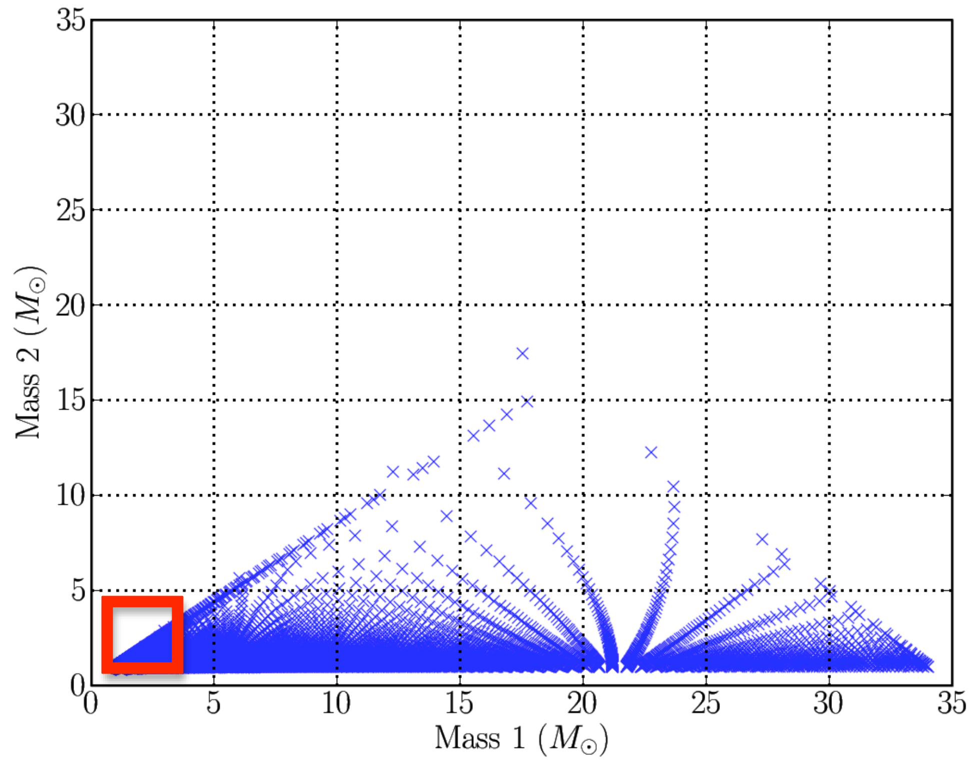
BNS



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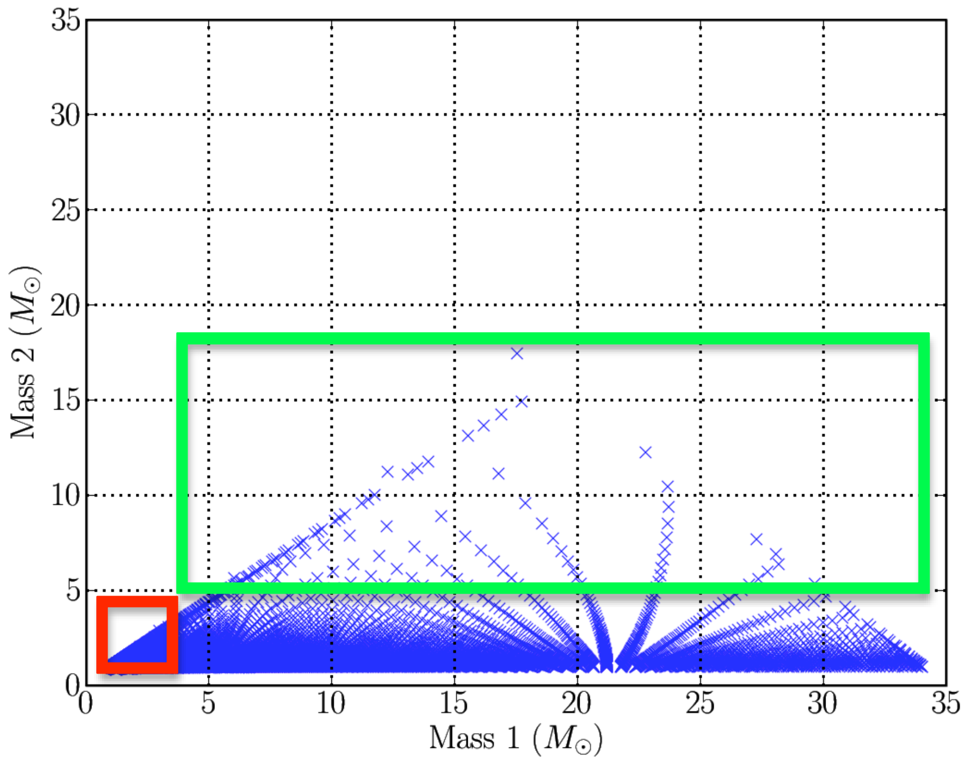
BNS
BBH



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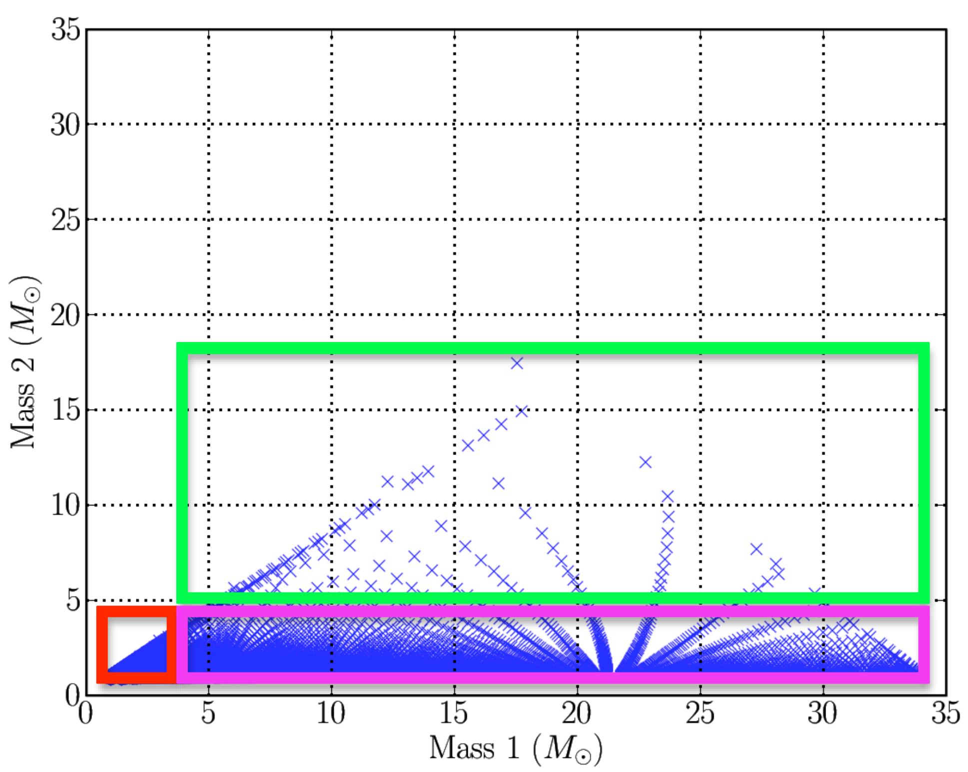

12-18 Month Overview

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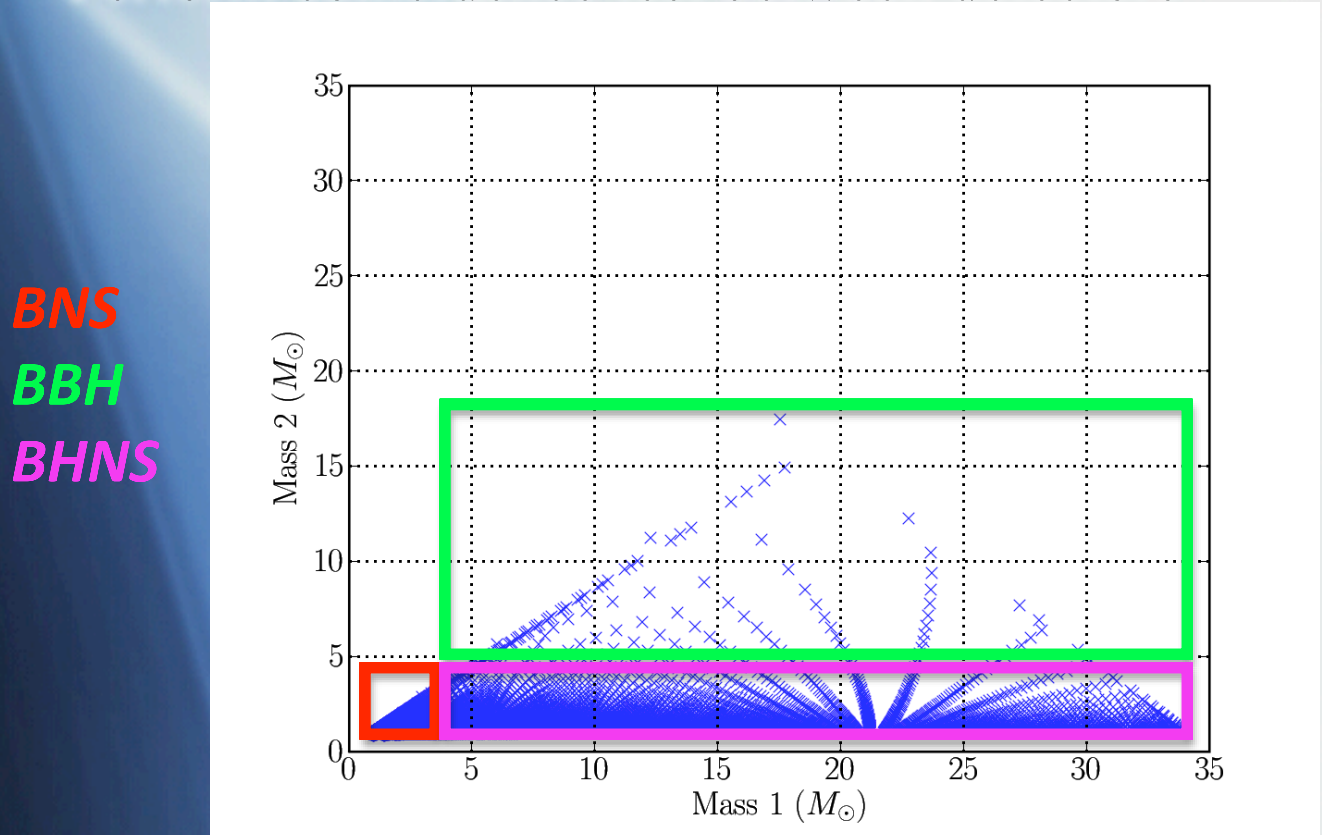
- Perform coincidence test between detectors



12-18 Month Overview

- Differences
  - ⇨ Search was divided into 7 “months”
    - Better background estimation
  - ⇨ Analysis more automated
    - Step toward more low latency analysis in the future

- Each month searched individually for gravitational wave candidates…

The Result?

- *No detection made*
- Loudest trigger had a false alarm rate of ~6 year$^{(-1)}$
  ⇨ Consistent with background

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12-18 Month Results

- Set upper limits on coalescence rates
  - ⇨ Calculate efficiency of detectors with injections
  - ⇨ Use uniform prior for each month
  - ⇨ Combine in a Bayesian manner using posterior rates from 1st year search
- Quoted in units of $L_{10}^{(-1)}$ $yr^{(-1)}$
  - ⇨ 1 L_{10} is 10^{10} times the blue light solar luminosity
  - ⇨ Milky Way contains ~ 1.7 L_{10}

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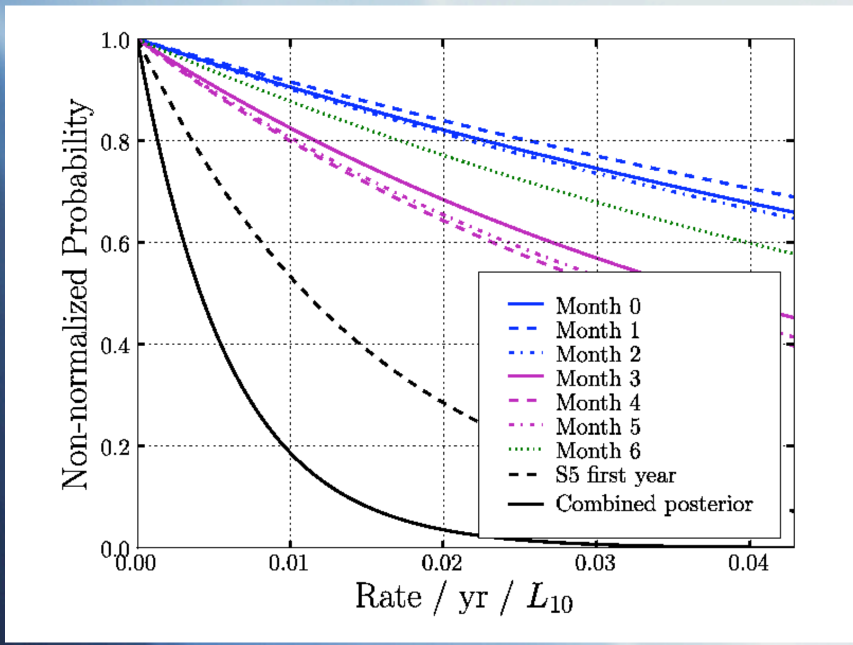
12-18 Month Results

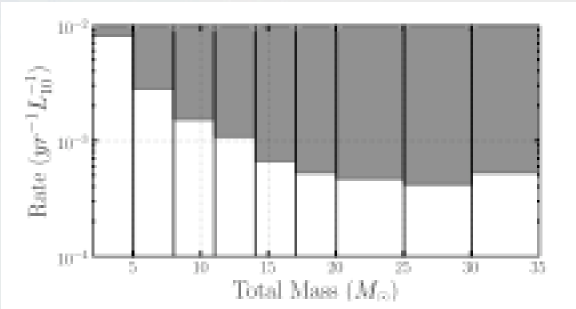
- UL Posteriors



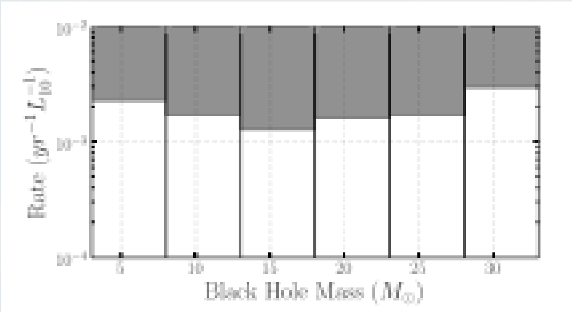
⇨ *BNS*

All plots at 90% confidence level

- ULs by mass bin



⇨ *BBH (vs. total mass)*



⇨ *BHNS (vs.bh mass, ns fixed)*

Rate Comparisons

Our results vs. Astrophysical Estimates (at 90% confidence):

- BNS $(1.35, 1.35)M_\odot$ = $1.4 \times 10^{(-2)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Optimistic* = $5 \times 10^{(-4)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Best Est.* = $5 \times 10^{(-5)}\ L_{10}{}^{(-1)} yr^{(-1)}$
- BBH $(5.0, 5.0)M_\odot$ = $7.3 \times 10^{(-4)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Optimistic* = $6 \times 10^{(-5)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Best Est.* = $4 \times 10^{(-7)}\ L_{10}{}^{(-1)} yr^{(-1)}$
- BHNS $(5.0, 1.35)M_\odot$ = $3.6 \times 10^{(-3)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Optimistic* = $6 \times 10^{(-5)}\ L_{10}{}^{(-1)} yr^{(-1)}$
  - ⇨ *Astr'phys. Best Est.* = $2 \times 10^{(-6)}\ L_{10}{}^{(-1)} yr^{(-1)}$

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What's next

- This Year
  - ⇨ LIGO-Virgo S5 low mass results
  - ⇨ LIGO S6 run, with improved sensitivity.
  - ⇨ Virgo VSR2, with improved sensitivity.
- 2014
  - ⇨ Advanced LIGO begins operation
  - ⇨ ~10x improvement in sensitivity = ~1000x volume
  - ⇨ Based on Astrophysical rates, detections expected!

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Thank You!

Extra: Background Estimation

- We time-slide the data between the two LIGO sites and look for coincidences
- Any time-slid coincident events cannot be from a true signal
- After performing 100 time-slides we can get a False Alarm Rate (FAR), for different types of triggers and IFO times
  - ⇨ We bin by mass range and detector combinations (e.g., H1L1, H1H2L1) when computing

- Using the FAR allows us to compare foreground triggers from different categories.