

# Searches for gravitational waves from compact binary coalescences (CBC) by the LIGO and Virgo Collaborations



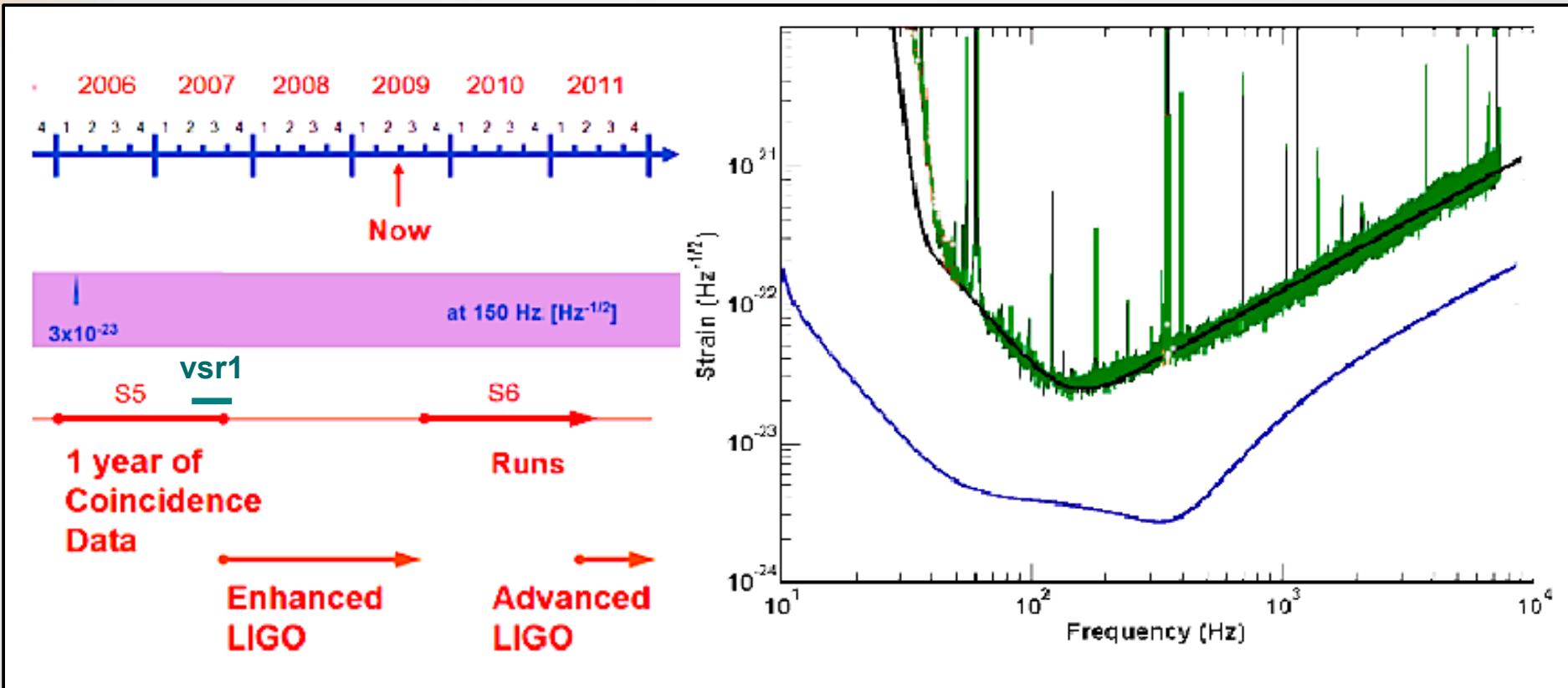
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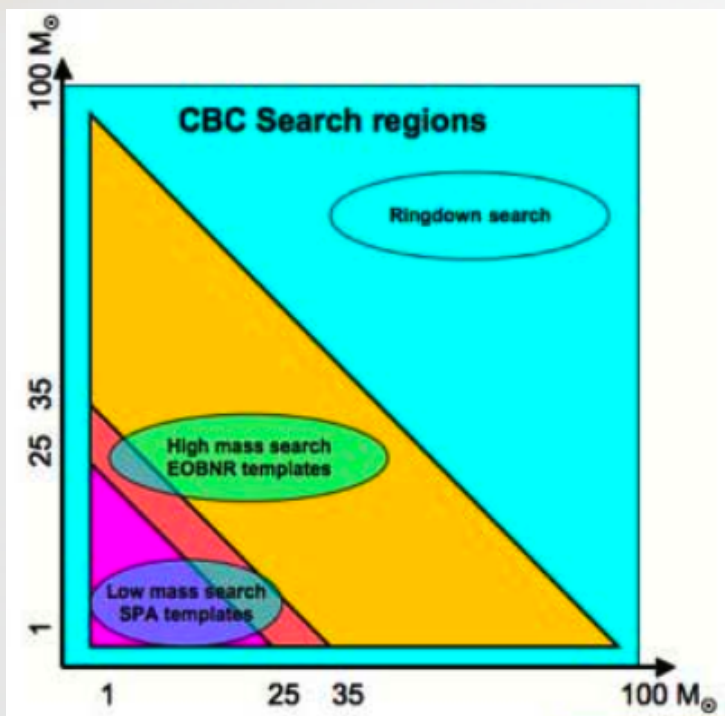
California Institute of Technology  
on behalf of the LSC and Virgo Collaborations

who we are, what we do

- Joint endeavour of LSC and Virgo collaboration
  - » about 50 scientists in US and Europe
- One of 4 such working groups
  - » Burst, continuous waves, stochastic
  - » data from LIGO, GEO600 and Virgo detectors
- Work in concert with the LIGO, GEO and Virgo instruments
  - » instrument scientists
  - » detection characterisation and calibration groups
  - » exploit the power and potential of the detectors
- Common scientific goals
  - » discover gravitational waves, measure rate of binary coalescences
  - » connection between CBC and GRBs
  - » Measure source parameters

## current and upcoming analyses





- $S_5$  low mass joint LIGO-Virgo analysis
  - » Month 19-24 of  $S_5$  data
- $S_5$  high mass search
  - » Full 2 year of  $S_5$
- $S_5$  ring-down search
- $S_5$  externally triggered (GRB)
- Follow-up and detection confidence
- Parameter estimation
- Others
  - » IMR studies
  - » spin
  - » Detector characterisation
  - » Preparing for upcoming science runs

- $S_4$  ringdown search
  - » paper approved
  - » has been submitted to arXiv/0905.1654
  - » will be submitted to PRD
- $S_5$  low mass 1<sup>st</sup> calendar year
  - » LIGO only data
  - » accepted to PRD [Phys Rev D 79\(12\):122001 \(2009\)](#)
- $S_5$  low mass 12-18 months
  - » in arXiv
  - » will be submitted to the PRD shortly
- GRB (externally triggered)
  - » advanced stage of analysis

using SPA frequency domain templates upto 35 solar mass

- Covers low mass binary systems
  - » SPA templates, 2 PN in phase up to ISCO
  - » Template bank at 3% minimal match
  - » Data filtered through template bank ( $\sim 5 - 7$  k)
  - » Automated via data analysis pipeline
- Historically divided into 3 searches
  - » first calendar year search
    - No detection candidates, in PRD
  - » 12-18 month low mass search
    - results finalised, to be submitted to PRD
  - » S5/VSR<sub>1</sub> LIGO-Virgo search
    - analysis nearly complete, paper to follow



using time domain EOB templates between 25 – 100 solar mass

- Covers binary systems upto 100 solar masses with some overlap with the low-mass search
- EOB time domain templates with merger and ringdown tuned to NR simulations
  - » non-spinning, IMR waveforms
  - » increases the bandwidth and the volume reach of detectors
- Analysis
  - » filtering, coincidence, signal based vetoes as in low mass
  - » Ranking of coincident triggers as in low mass
  - » month by month analysis
- Craig Robinson's talk

preparation for S6 / VSR2 - weekly science !

- S4 paper submitted and is publicly available  
arXiv/0905.1654
- Plans for S5
  - » Parameters of the search
  - » S5 24 months divided up into 3 month blocks
  - » borders coinciding with the S5 high mass search
- Structure of the search similar to S4
  - » new coincidence algorithm
  - » lowers false alarm rate
- S5 progress
  - » tuning coincidence algorithm using full coalescence waveforms and also ringdown waveforms
  - » veto segments, analysis in progress
- Plans for S6



## 22 short hard GRBs in S5 data

- 213 GRBs identified by X-ray and Gamma-ray instruments during S5
  - » Short hard GRBs for merger progenitor
    - $30 + 2 + 1 = 33$
  - » 22 had enough data to be analyzed
- GRB 070201 already analyzed before
  - » high priority as spatial coincidence with M31 (780 kpc)
  - » null result excludes compact binary merger in M31 as source with  $> 99\%$  confidence
- Analysis
  - » segmenting, thresholding, coincidence
  - » population statement
- Nickolas Fotopoulos' talk

## S5 (month 19-23) / Virgo VSR1 data

- LIGO S5 run spanned 2 years (Nov 2005 – Sep 2007)
- Virgo's first science run (VSR<sub>1</sub>) coincided with the last 5 months of S5 run.
- Full data sharing between collaborations
  - » allows for the first joint LIGO-Virgo CBC search
  - » new challenges
- New ranking statistic of CBC triggers found useful
- Status of the analysis
  - » upper limits being set
  - » within 1 – 2 orders of magnitude of the astrophysical optimistic rates
- Ruslan Vaulin's talk

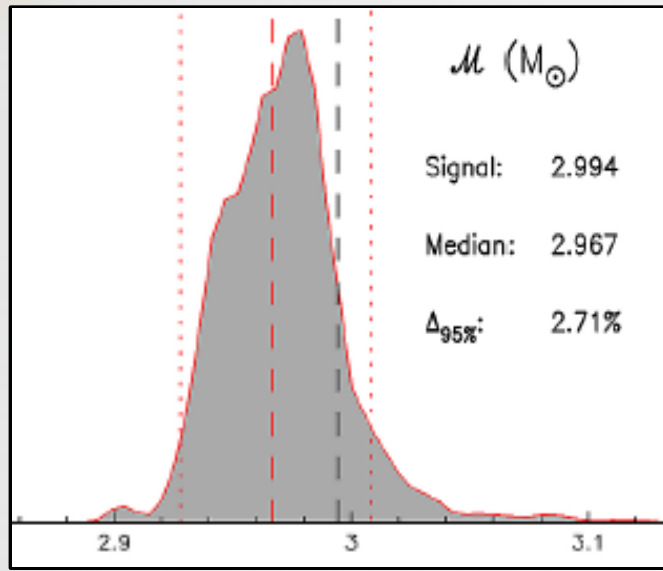
preparation for S6 / VSR2 - weekly science !

- Beginning with S6 / VSR2
  - » weekly runs based on current pipeline
  - » very low latency search
    - limited mass range, higher threshold, triple coincidence
    - MBTA is running now
    - technologies being developed/tested in E13/E14
- Motivated by
  - » Chance for EM follow-up by quick identification and localization of interesting candidate
  - » establishing external collaborations
    - look for EM counterparts in different wavelengths
- Frederique Marion's talk

part of our follow-up regimen

- Bayesian analysis

- » data from arbitrary network of detectors
- » extraction of the parameters of the signal in the data
- » posterior probability density functions (PDF) for parameter estimation using MCMC techniques.



### Posterior PDF

- » full multi-dimensional PDF can be computed
- » usually represented as marginalised 1D PDF
  - provides parameter values and uncertainty
- » different types of inspiral templates employed

- Vivien Raymond's talk

improvements to present algorithms, adding new features

- Improved templates
  - » Spin
  - » numerical relativity inspired waveforms
- New analysis techniques
  - » hardware accelerated signal processing
  - » multi-dimensional event classification
  - » coherent methods
- Detector characterisation
- Follow-up
- Inspiral-Merger-Ringdown searches
- Bayesian likelihood methods
- Parameter estimation

working towards confidence in the first detection

- CBC group: joint LIGO-Virgo collaboration with data sharing
- Primary focus is to finish  $S_5$  analysis
  - » papers published
  - » different stages of maturity
- Many new techniques being implemented by the group
  - » detection confidence
  - » parameter estimation
  - » parameter space coverage
  - » improve sensitivity of our searches
- Preparing for upcoming  $S_6/VSR_2$  data analysis
- Exciting times