First Comparison Between LIGO & Virgo Inspiral Search Pipelines

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LIGO-Virgo Joint Working Group

LIGO-G050057-00-Z

Goals

Many benefits of using multiple detectors

- decreased false rate
- increased sky coverage and live time
- obtain sky location and polarization
- independent detection on several continents

Also, many issues

- different sensitivities
- different sampling rates
- different search algorithms
- different formats for storing data, triggers

Goal of LIGO-Virgo joint working group

- begin addressing the issues,
  so we are ready to reap the benefits

LIGO ± Virgo Mock Data Challenge

Exchange simulated LIGO and Virgo data containing Neutron Star inspiral injections

Analyze both data sets with three methods:

- LIGO pipeline
- Virgo Merlino pipeline
- Virgo Multi-Band pipeline

Fix common search parameters:

- Inspiral component mass range 1 to 3 M
- Template bank minimal match 95%
- SNR threshold 6
- Starting frequency 30 Hz for Virgo data, 40 Hz for LIGO data

Compare parameter recovery of injected events

Data Generation

3 hours of LIGO & Virgo noise

- Design sensitivities with line features
  - 16384 Hz & 20 kHz

Inspiral events injected

- 2nd Order Post-Newtonian

- 26 in LIGO data (every ~400s)
  - distances 20, 25, 30, 35 Mpc
  - masses 1.4-1.4 and 1.0-2.0 M
  - Starting frequency 40 Hz

- 11 in Virgo data (every ~ 900s)
  - SNR = 10 , distance=24.83 Mpc
  - masses 1.4 ± 1.4 M
  - starting frequency 24 Hz

The LIGO Pipeline

- Split data into analysis chunks of overlapping segments.
  - Create template bank for each analysis chunk.
  - Filter data, record triggers if SNR above threshold.
  - Cluster triggers within duration of template, not between templates in the bank.

LIGO $\pm f_{low} = 40$ Hz

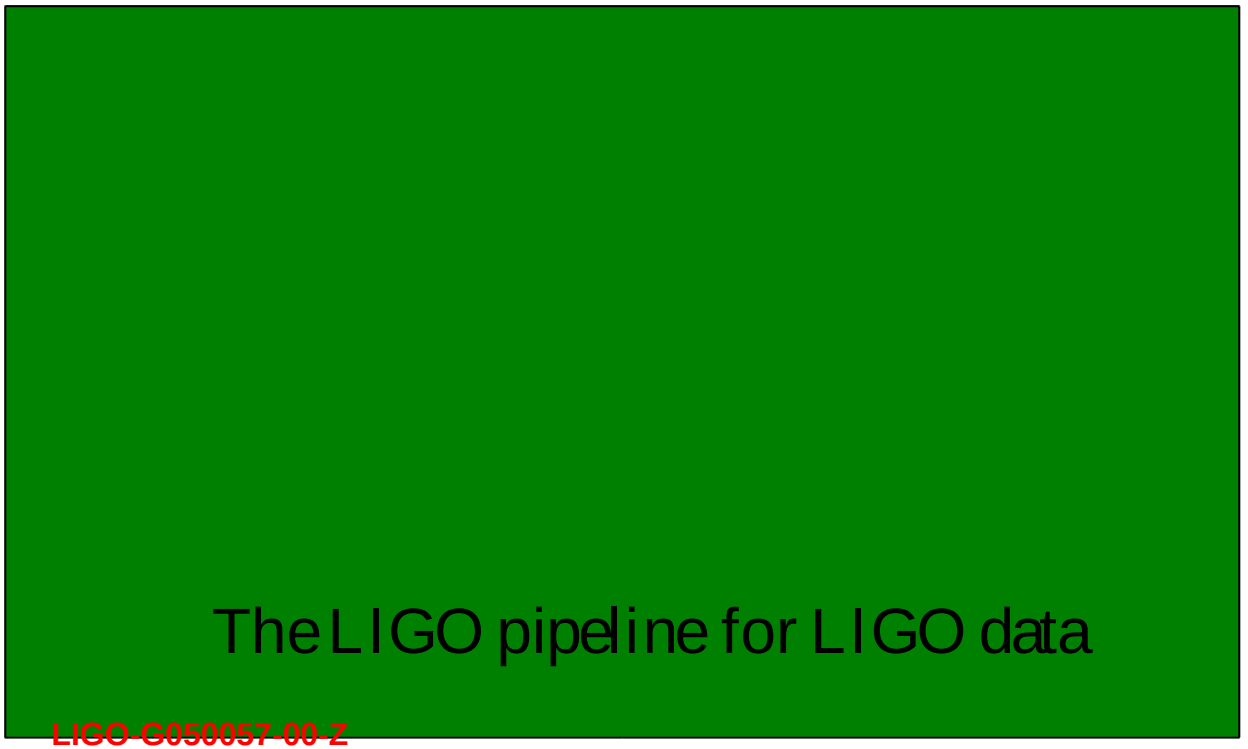
longest template = 45 s

segment length = 256 s

Virgo $\pm f_{low} = 30$ Hz

longest template = 96 s

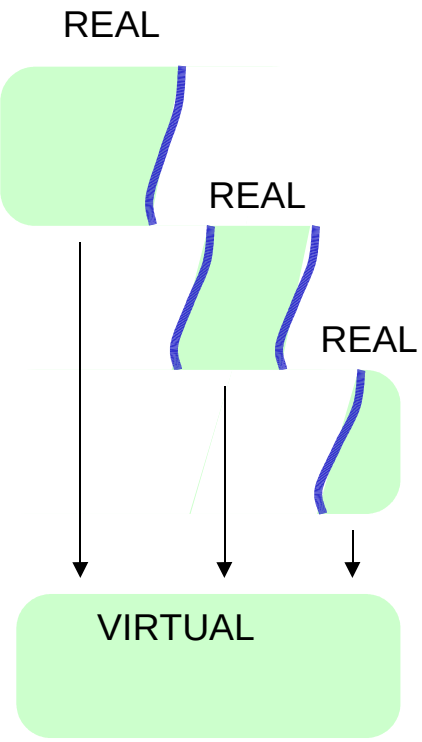
segment length = 512 s



The Virgo Multi-band Pipeline

Initialization

- Spectrum (on 1800 s of noise)
- Grid of full frequency band (VIRTUAL) templates
- Grids of (REAL) templates for each frequency band



Processing

- Run synchronously each grid of REAL templates on data
  - Data chunk twice the longest REAL template
- Check if any REAL template triggers
- Recombine associated VIRTUAL templates
  - Coherent sum of real templates outputs:
    - Þ Obtain VIRTUAL templates triggers
- Cluster, in time and between templates

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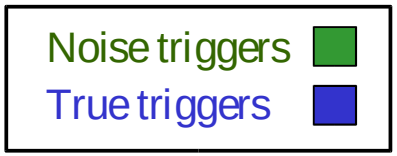
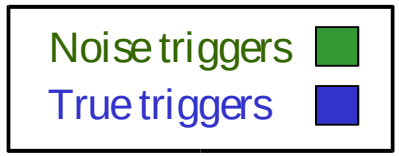
Trigger Production Comparison

	LIGO data	Virgo data
LIGO pipeline	~3500 Templates UWM Cluster (1 GHz Pentium II) 6 jobs => 6 time slices total time 46 h	~9500 Templates CalTech Cluster (Xeon 2.66 GHz) 3 jobs => 3 time slices total time 88 h
Virgo Multi-Band	~1950 (VIRTUAL)Templates Xeon 2 GHz 2 jobs => 2 mass space regions total time 15h	~6190 (VIRTUAL) Templates Xeon 2 GHz 7 jobs => 7 mass space regions total time 38 h
Virgo Merlino	2556 templates Cluster of 7 Xeon 1.7 GHz 8 jobs total time 16 h	8103 templates Cluster of 7 Xeon 1.7 GHz 23 jobs total time 48h

Trigger Comparison

Triggers are tagged ªtrueº if time is within 20 ms of an injection





Virgo Multi-Band:
Due to clustering, at most one trigger per injection

LIGO Pipeline:
Many triggers per injection, use the one with highest SNR

Parameter Estimation (distance)

LIGO data

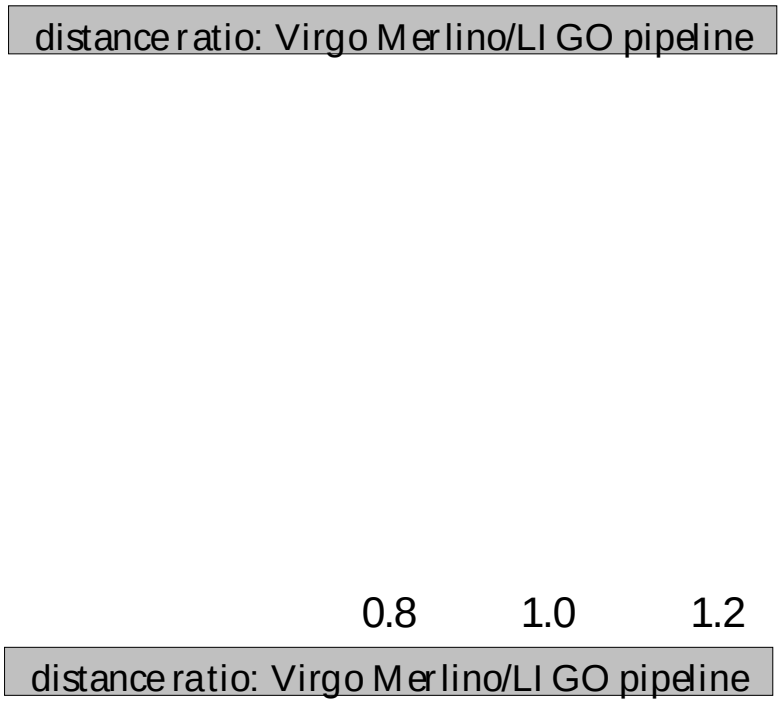
Virgo data

Injections recovered by all pipelines

- some injections at 35 Mpc not seen

Strong correlation between recovered distances

Parameter Estimation (distance)



LIGO data

Injections recovered by all pipelines

- some injections at 35 Mpc not seen

Virgo data

Strong correlation between recovered distances

0.8 1.0 1.2 1.4 1.6

Parameter Estimation (time)

LIGO data

No correlation, Multi-Band spread 6 times larger than LIGO pipeline

- Due to known (fixable) error in Virgo Multi-Band Analysis implementation

Parameter Estimation (mass)

Relatively large spread in recovered component masses.

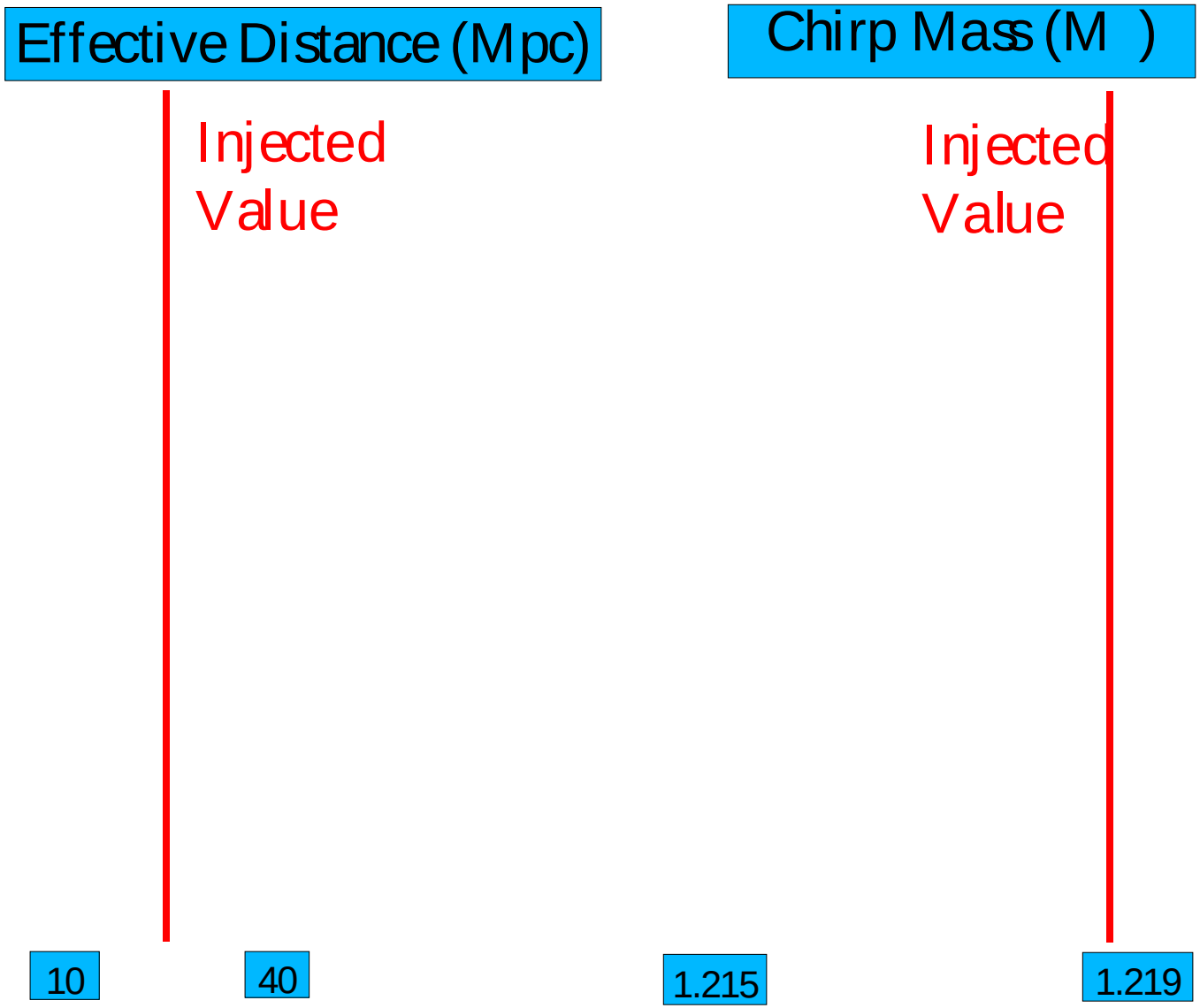
- Dependent on precise placement of templates in grid.

Chirp mass recovered very accurately.

LIGO data

Virgo data

Post-processing (LIGO pipeline)



Create posterior probability distribution of inspiral parameters

Achievements

Successfully exchanged and analyzed each others' data

- All pipelines ªfindº the injected signals
- Wrote a trigger format translator

Parameter Estimation:

- Strong correlation between recovered parameters
  - SNR
  - distance
  - chirp mass
- Would like to reconcile remaining differences
  - around 10 % in worst case
  - leads to better understanding of all pipelines

The next step:

- Injection of astrophysical events, from given sky location
- Determine injection parameters using multiple instruments
  - recover sky location

Parameter Estimation (SNR)

LIGO data

Virgo data

Same events detected, Strong SNR correlation between pipelines

Virgo data: All events found by both pipelines

LIGO data: 1 event missed by both pipelines + 1 missed by Virgo MB (near threshold)

Parameter Estimation (SNR)

SNR ratio: Virgo Merlino/LIGO pipeline

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Virgo data

Also for Virgo flat search