



GRB triggered inspiral searches for gravitational waves in LIGO data

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- Gravitational waves and S5
- GRB-triggered inspiral searches
- Analysis and results for GRB 070201
- Outlook

Different Sources

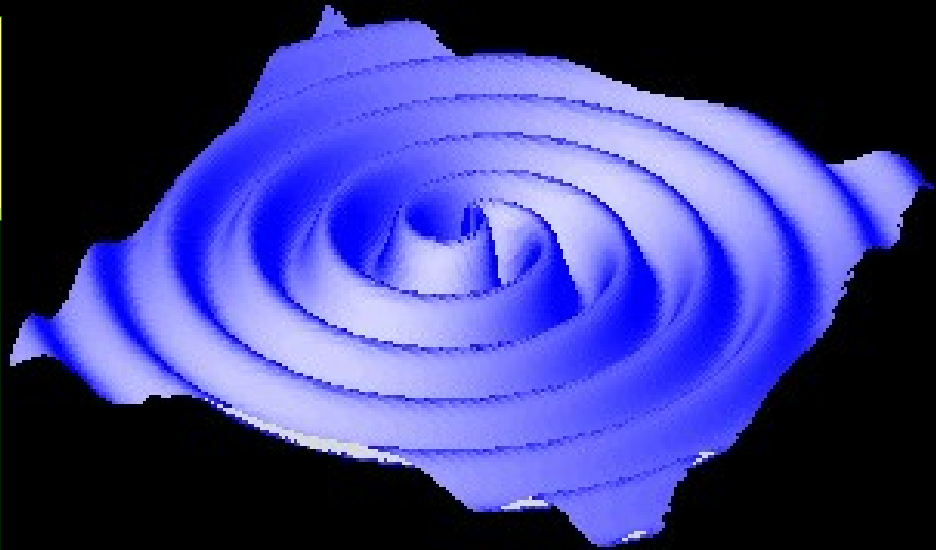
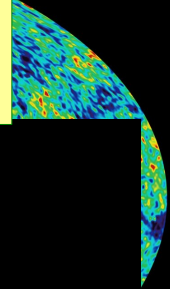
Burst searches

Stochastic searches

Inspirational searches

The unknown...

?



Detector Sites

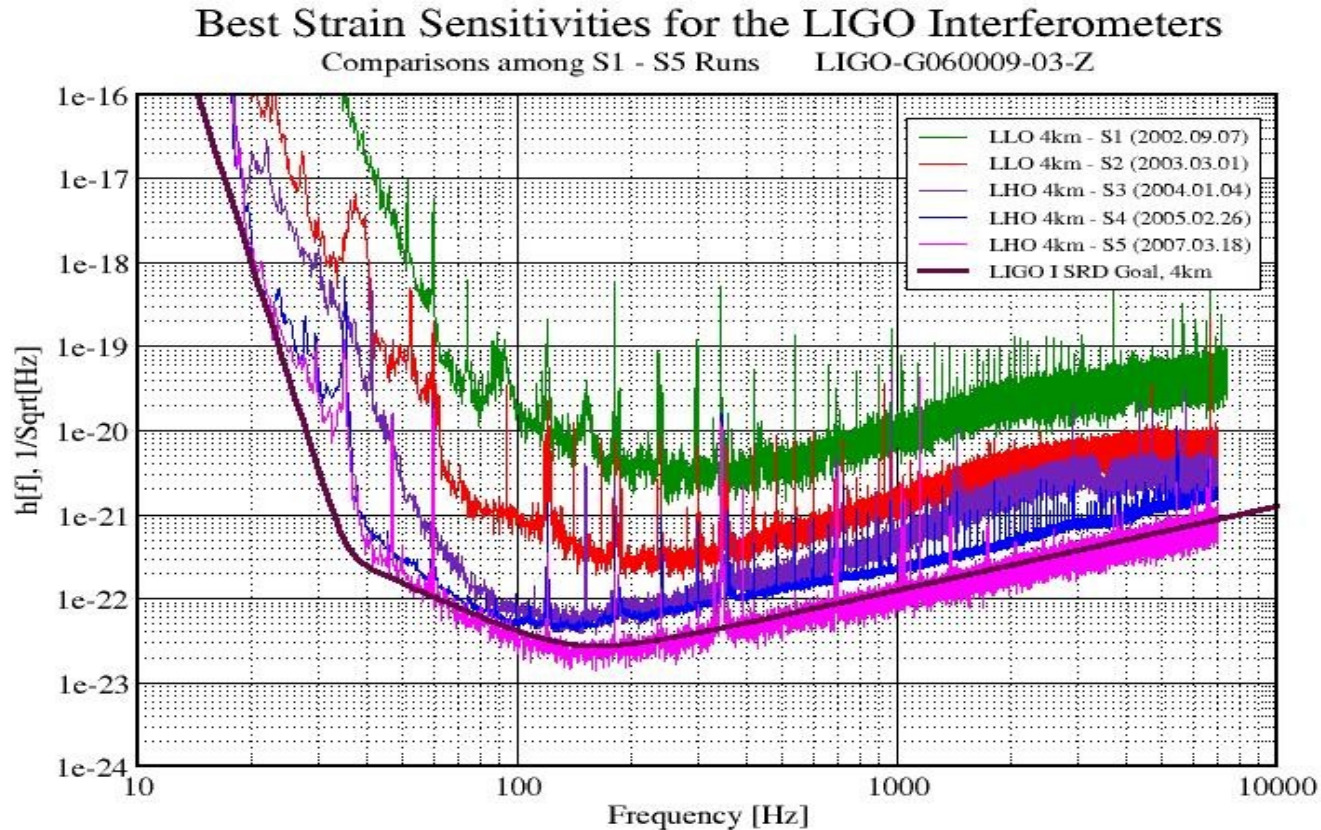


kyo Japan
ferometer

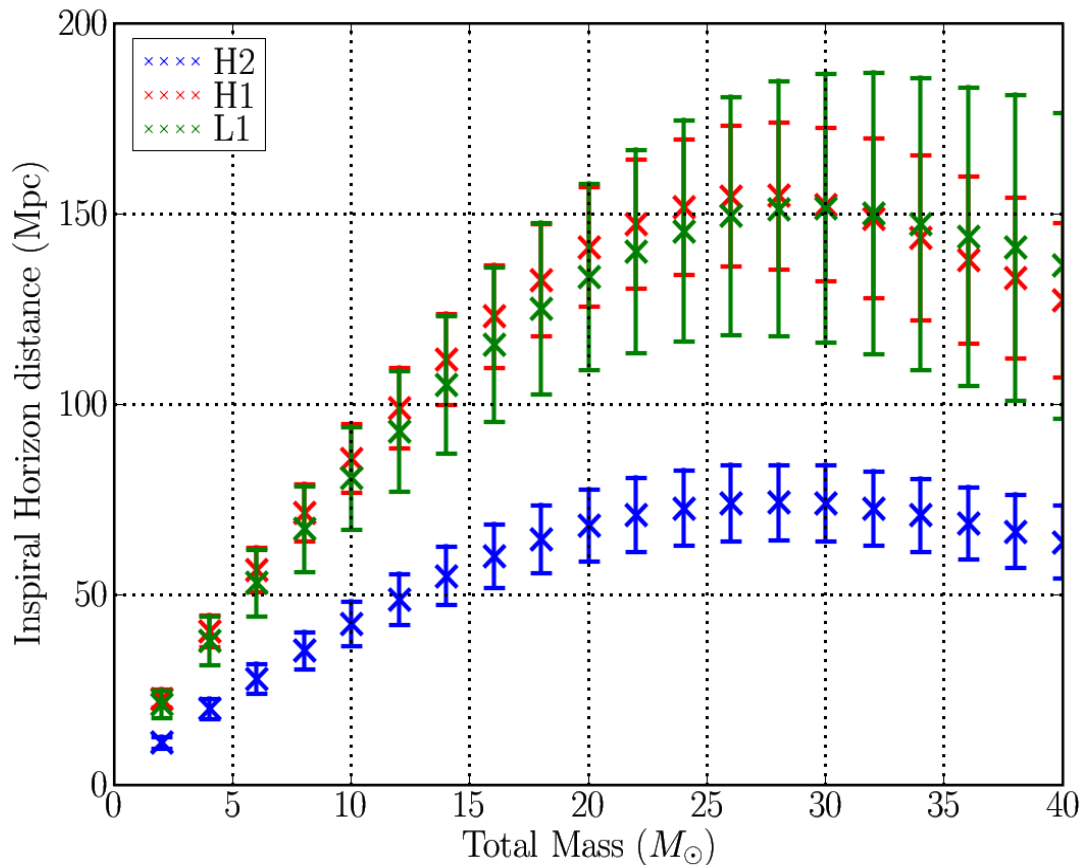
s supplier

n

LIGO recently finished a 2 year science run (S5)



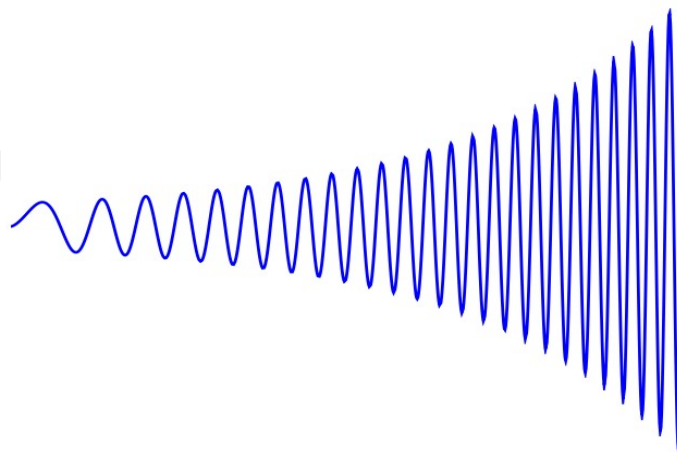
Horizon distance for the LIGO detectors

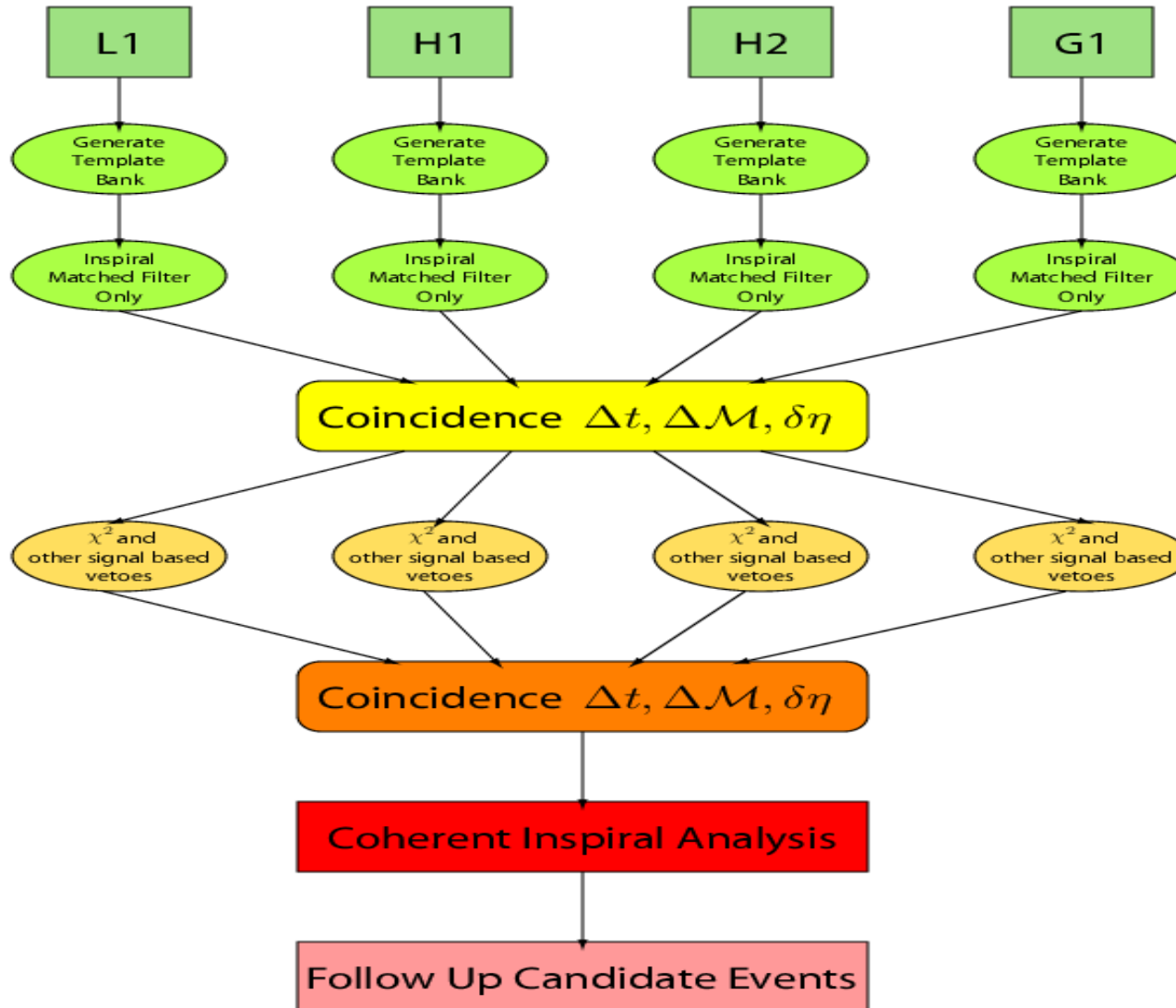


Horizon distance:
 Distance for an optimal located and oriented binary that would produce a SNR of 8

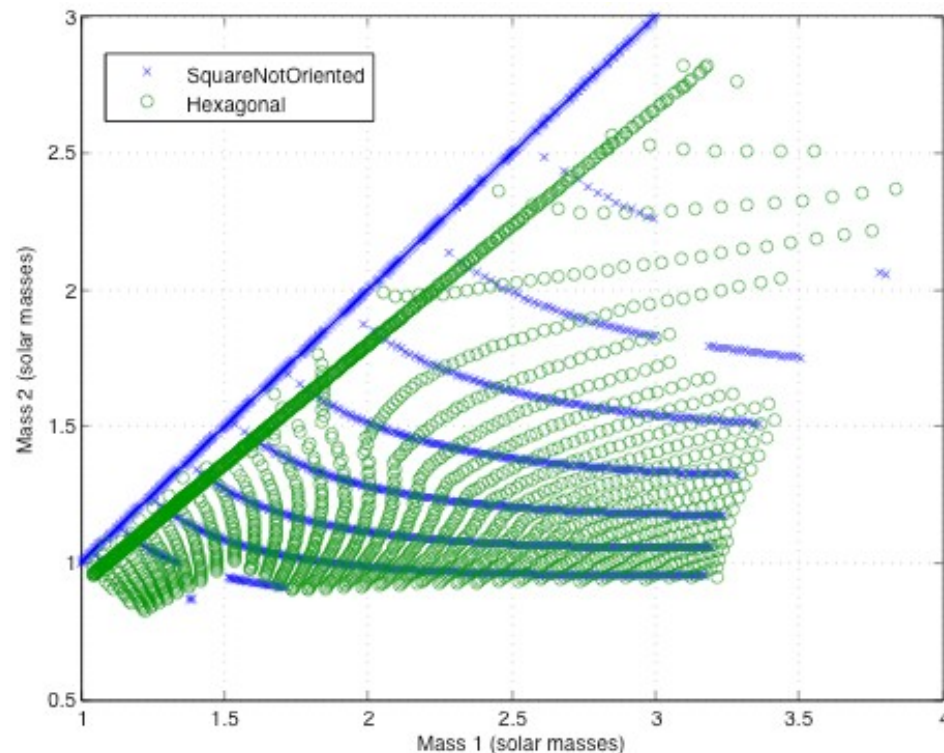
- Burst Search:
 - Search for un-modeled burst of GW
 - Cross-correlation between two data streams or coherent search (see Patrick's talk)

- Inspiral search:
 - Search for a modeled GW (post-Newtonian waveform)
 - Cross-correlation between data and predicted waveform





- Template Bank:
 - Covers physical parameter space (i.e. Masses)
 - Placing so that any signal in between has maximum 3% mismatch with closest template



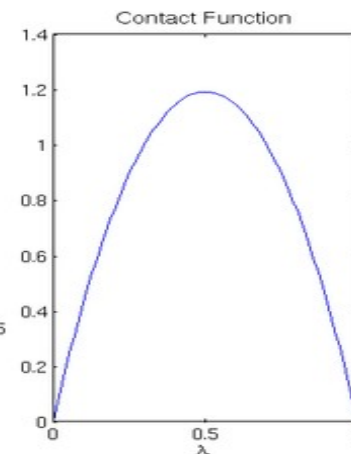
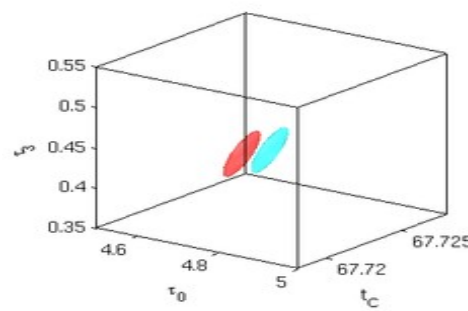
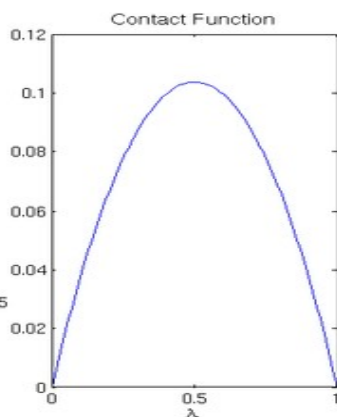
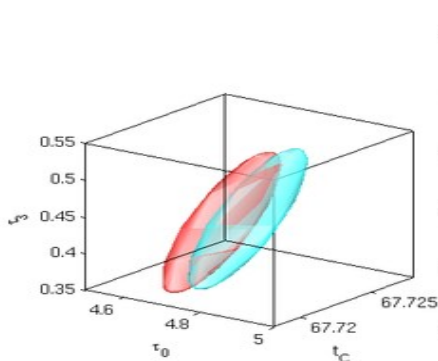
- Matched filtering:
 - Cross correlation of data with a template
 - Best method to identify known signal in Gaussian noise

The diagram shows the matched filtering equation with several components highlighted by colored boxes and ovals:

- A red box labeled "data" is positioned above the $s(f)$ term, which is circled in red.
- A blue box labeled "template" is positioned above the $h^*(f)$ term, which is circled in blue.
- A green box labeled "SNR" is positioned above the ρ^2 term, which is circled in green.
- An olive box labeled "Power spectral density (norming)" is positioned below the $S_h(f)$ term, which is circled in olive.

$$\rho^2 \propto \int \frac{s(f) h^*(f)}{S_h(f)} df$$

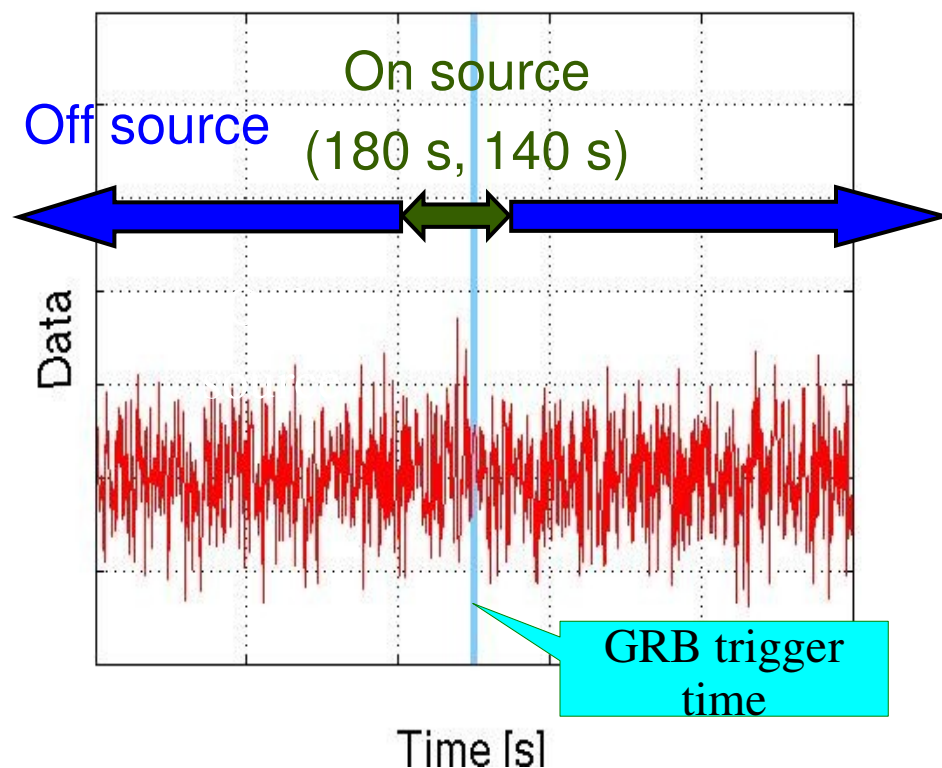
- Coincidence:
 - Each trigger is assigned an ellipsoid in 3-dimensional parameter space (t_c , m_1 , m_2)
 - Two trigger *coincident*, if ellipsoid overlap
 - Scaling of ellipsoids: Determined from metric and simulations



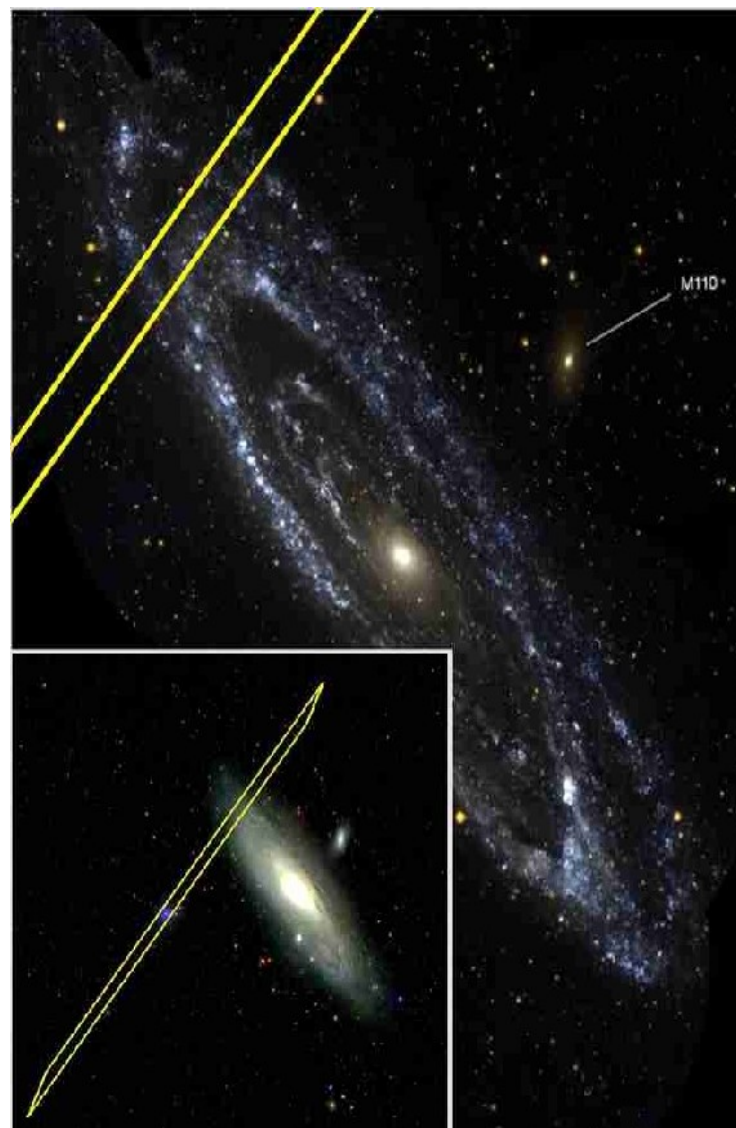
- Long GRBs ($t > 2\text{s}$):
 - Core-collapse of massive stars
 - Supernovae identified with long GRB
- Short GRBs ($t < 2\text{s}$):
 - Origin still unknown
 - Increasing hints for merger progenitor
 - Are there any subclasses (SGR, NSNS, NSBH)?
 - Theoretical updates?

- Un-triggered search
 - Location and time of a putative GW source unknown
- Triggered search:
 - GRB gives time and sky location
 - Gives geometrical time-delay between different detectors
 - The GRB triggered search can probe deeper into the data (lower SNR threshold)

- Background
 - Determined by off-source segments
- Foreground:
 - Determined by on-source segment
 - What is a reliable on-source window length?



- Short GRB ($T_{90}=0.15$ s)
- Possible compact binary merger (NS/BH)
- Possible SGR
- Error-box of location overlay M31 ($D \simeq 770$ kpc)
- See: [arXiv:0711/1163](https://arxiv.org/abs/0711.1163), accepted by ApJ



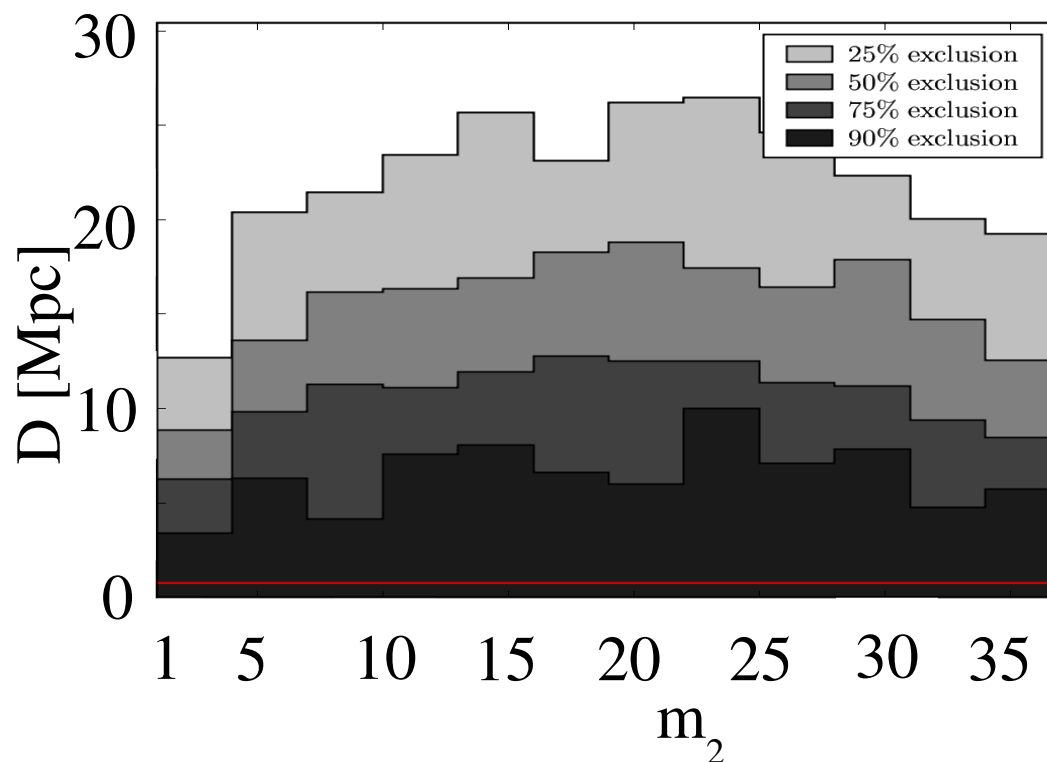
Inspiral search:

- Search for a modeled GW (post-Newtonian waveform)
- Parameters: $m_1 = [1.0, 3.0] M_{\text{sol}}$
 $m_2 = [1.0, 40.0] M_{\text{sol}}$
- Cross-correlation between data and waveform (matched filtering)
- SNR thresholds: 5.5 in H1, 4.0 in H2

No gravitational wave detected

Inspirational search:

- ◆ Binary merger in M31 scenario excluded at >99% level
- ◆ Exclusion of merger at larger distances: see plot



Some statistics:

- ★ 213 GRB observed electromagnetically during S5
 - ★ 30 short (8 with measured redshift)
 - ★ 182 long (58 with measured redshift)
- ★ Longest: 900 sec, Shortest: 0.028 sec
- ★ Nearest: $z=0.0331$ (~ 150 Mpc), farthest: $z=5.11$

- LIGO detectors:
 - Working at design sensitivity
 - enhanced LIGO (~2009), factor of 2 improvement
 - advanced LIGO (~2014), factor of 8 improvement
- GRB 070201: ([arXiv:0711.1163v1](https://arxiv.org/abs/0711.1163v1))
 - No GW signal for merger in M31
 - Cannot exclude SGR in M31

➡ Future:

- ➡ Inspiral analyses on short GRB's during S5 underway
- ➡ Extend inspiral search to *all* GRBs with LIGO data available
- ➡ Include statistical analysis

- News on progenitor theory?
- Subclasses for short GRB's?
- Reliable on-source window length?