SEARCH FOR COALESCING BINARIES GRAVITATIONAL WAVES SIGNAL ASSOCIATED WITH GRB070219A USING THE VIRGO DETECTOR

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Motivations

Virgo has taken scientific data during the Week-end Science Run 9 (WSR9) on February 17-19, 2007. The gamma ray burst GRB070219A occurred during that run. Though not being a short GRB (17 s long), thus probably not being a binary neutron star coalescence event, we decided to use it as a training and test bench for our analysis of coincident GRB-binary coalescence events.
The results given hereafter are to be considered as preliminary.

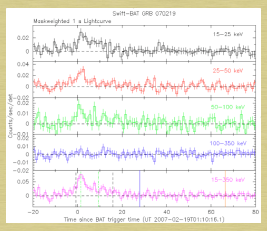
Data analysis principle

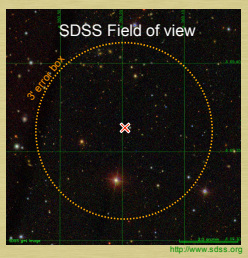
A coalescing binaries signal is searched for using a matched filtering technique. Called Multi Band Template Analysis (MBTA), it uses a set of templates in two frequency bands and recombines the two outputs giving a set of candidate events. The signal over noise (SNR) values and distribution of the events are then compared in two regions, a 3 min. "ON" region around a time of the observed GRB, and a 2 hours "OFF" region as a background around this time. A set of modeled signals are injected in the background region to make the efficiency studies.

GRB070219A and its visibility

This GRB was seen by Swift[1] and happened during the WSR9 run of Virgo.

Time : 19/02/2007 01:10:16 UT
Duration : 17 s, a (not so) long burst
Position : ra=260.198 (17:20:47.5), dec=69.3640 (69:21:50.4), no optical counterpart





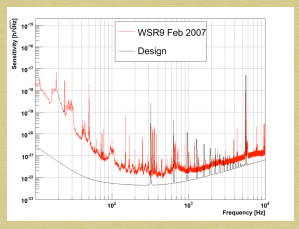
The antenna pattern function of Virgo at the time of the GRB was

$$F = \sqrt{F_+^2 + F_\times^2}/\sqrt{2} = 0.511$$

which means the event is not in the blind region of Virgo

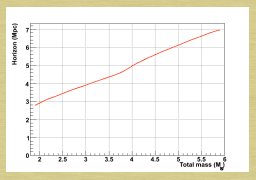
[1] GCN report 33.2 24Feb07 (http://gcn.gsfc.nasa.gov/reports/report_33_2.pdf)

Data and sensitivity



The sensitivity of the Virgo detector during the WSR9 period is shown on the left, as well as the design sensitivity.

The figure showing the optimal horizon as a function of total mass of the binary system allows to get a feeling of the Virgo detector reach at the time of the GRB event.

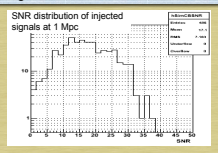


Model and injections

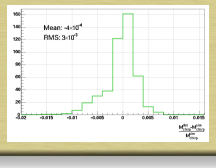
In order to measure efficiencies, 3000 simulated injections were made in the "OFF" region. The injected signals correspond to coalescing binary neutron star systems and have the following characteristics :

- ✓ the waveforms are calculated using a second order Post-Newtonian (Taylor) approximation
- ✓ mass of the components: uniform distribution in [1;3] $M_\odot$
- ✓ polarization angle : uniform in [0;2π]
- ✓ inclination angle : cos(ι) uniform in [-1;1]
- ✓ Apparent source location and orientation with respect to the Virgo detector : fixed longitude at RA = 260.1916, DEC = 69.370

The set of injections was distributed in distance with 6 fixed values : 1, 2, 3, 4, 5 and 7 Mpc. The SNR distribution for the 1 Mpc injected events is shown in the figure below.



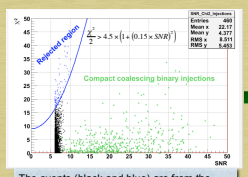
All the 1 Mpc injected events with simulated SNR above 6 were detected using the MBTA algorithm. The chirp mass is properly reconstructed with a resolution of 0.3% as shown in the following plot.



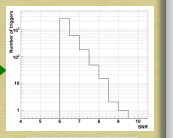
Background analysis

A 3 min. ON region was defined around the time of the GRB (2 min. before and 1 min. after), as well as two one-hour OFF regions for background studies. The analysis was then carried out with the MBTA algorithm (see above), using two frequency bands ([100;230] Hz and [230;2000] Hz). Events with SNR>6 were selected.

A χ^2 was defined to measure the consistency of the signal frequency distribution between each event and the analysis templates for the two bands used in the MBTA algorithm.
A cut in the SNR-χ^2 plane is then applied.

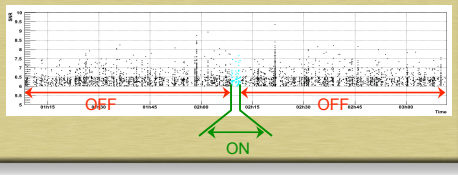


The events (black and blue) are from the OFF region without simulated data.The cut is safe for the a-posteriori injected events, as shown above.



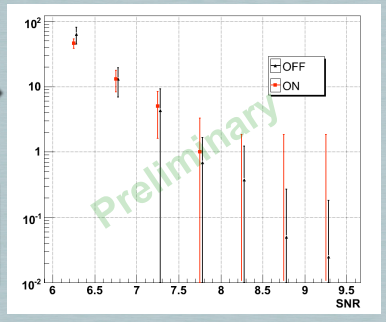
No events above SNR=9.05

SNR of the selected events as a function of time. The SNR and SNR-χ^2 cuts are applied.



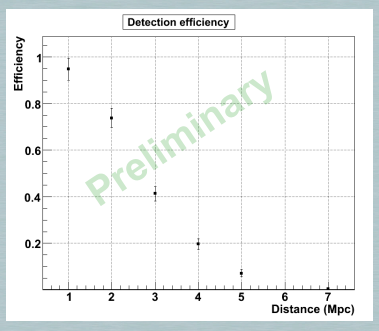
Preliminary results

The compatibility between the SNR distributions of the background OFF and ON regions was verified.
No event above SNR=7.8 was found in the ON region. The distribution in the ON region is perfectly consistent with the estimated background distribution.



The number of events are scaled proportionally to the length of the ON and OFF regions. The errors of the OFF region are determined by computing the RMS of the distribution on small 3 min. segments.

After "opening the box", verifying the compatibility of background distributions in the ON and OFF regions, the efficiency of finding an event with SNR>SNR_{max}=7.8 in the data for the six injected distances was built.



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