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TAKING PARAMETER CORRELATIONS INTO ACCOUNT IN THE BINARY INSPIRAL PIPELINE

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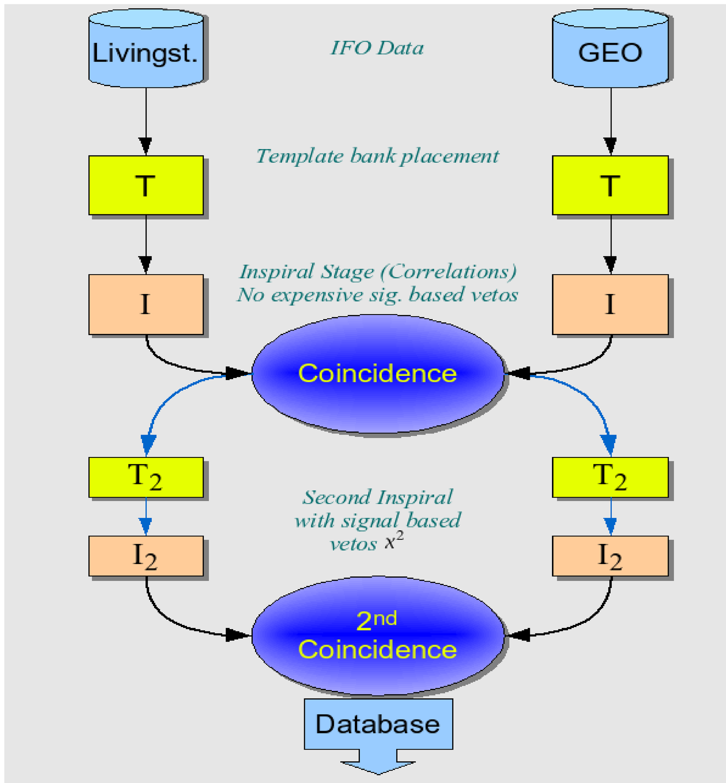
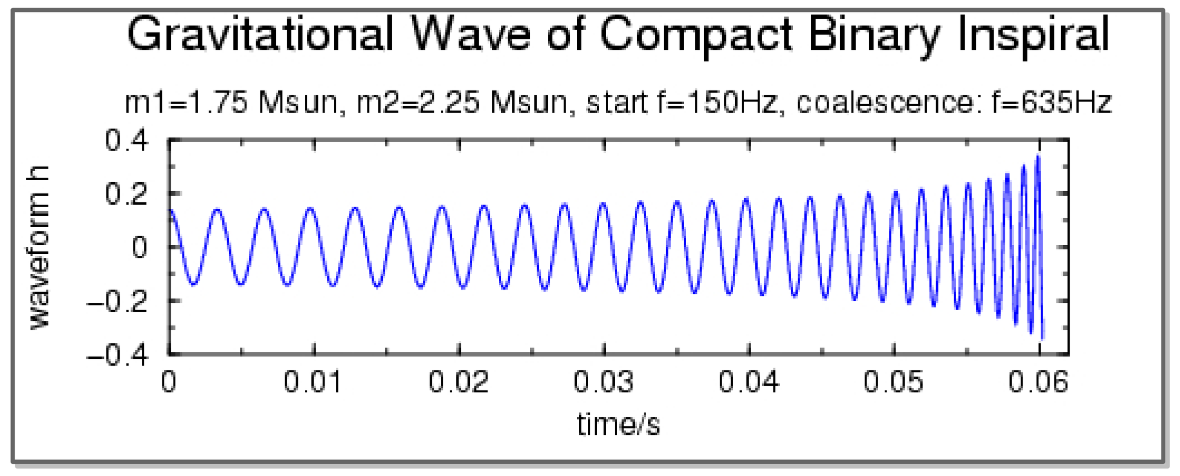
Need for trigger rate management

Data from gravitational wave detectors like LIGO will be analysed for signatures of astrophysical 'chirp' signals from inspiraling compact binaries. This involves correlating the data against a set of template waveforms, resulting in a set of `triggers' as the filtered output. The rate of raw unclustered triggers produced by the inspiral data analysis pipeline can be prohibitively large for subsequent analyses. At a single interferometer level, an appropriate clustering algorithm is required in order to reduce the number of triggers to a manageable level. When considering triggers from multiple interferometers, one can demand coincidence in the trigger parameters in order to retain 'interesting' candidates - thereby reducing the coincident trigger rate.





We present two new techniques for clustering single interferometer triggers and finding coincidences. The methods detailed here make use of the parameter space metric, and thus take into account information regarding correlations between parameters.

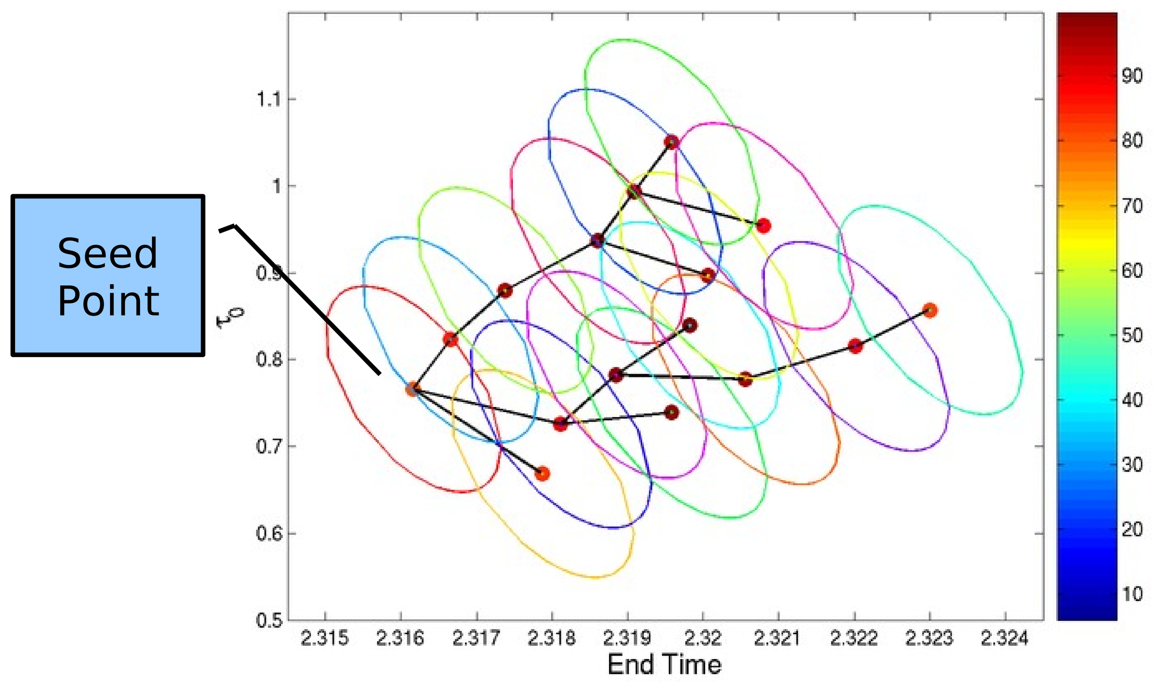
TrigScan: A simple algorithm for clustering inspiral triggers

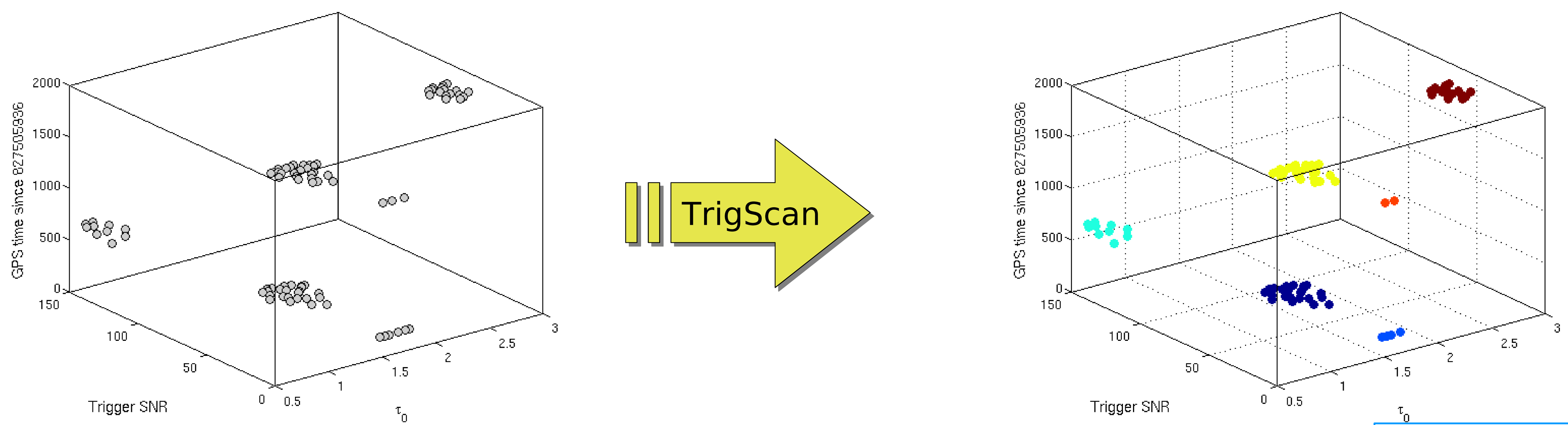
To discover a cluster, TrigScan starts with an arbitrary point **p** and retrieves all the points in the list that are 'reachable' from it by the method of overlaps. A cluster is to have at least 2 members.

If **p** is successful in agglomerating points then this yields a cluster with members tagged by a common cluster ID. The loudest trigger in each such cluster is retained and written to the trigger database.

If **p** does not agglomerate into a cluster, tagged as NOISE (or singleton, or straggler).

Implementation greatly simplified by time ordered raw triggers simple form of the contact function to be maximized whilst checking for overlaps of ellipsoids

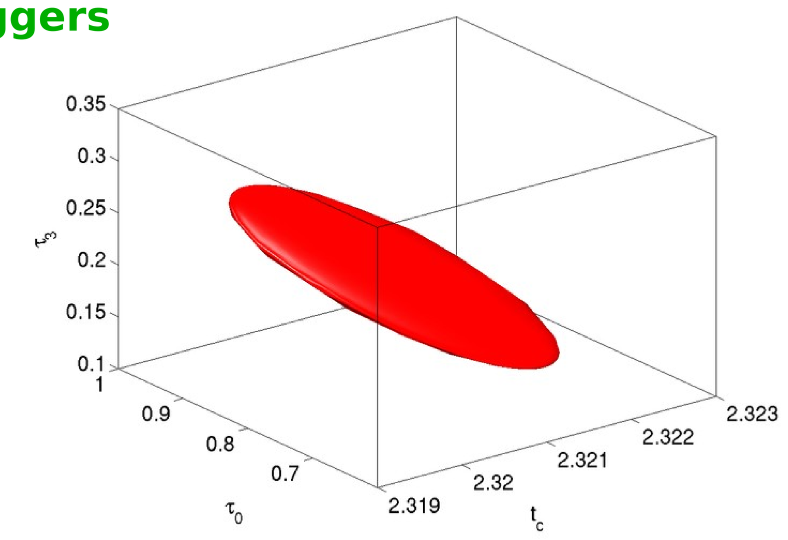




An ellipsoidal model of triggers

We model the triggers as ellipsoids in the three dimensional space (t_c, τ_0, τ_3)

An ellipsoid is characterised by the position vector $\vec{r}$ of the trigger and the 'shape' matrix $\mathcal{G}$ which depends on the metric and encodes the local correlation of parameters.



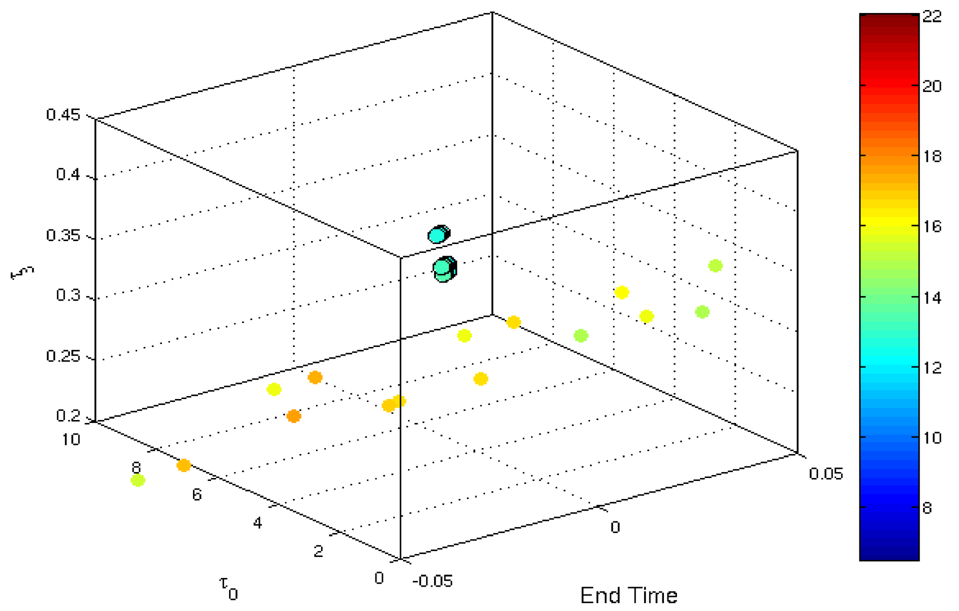
$$\mathcal{E}(\vec{r},\mathcal{G}) = \left\{\vec{x} \in \mathcal{R}^3 \mid (\vec{x}-\vec{r})^T \, \mathcal{G} \, (\vec{x}-\vec{r}) \leqslant 1\right\}$$

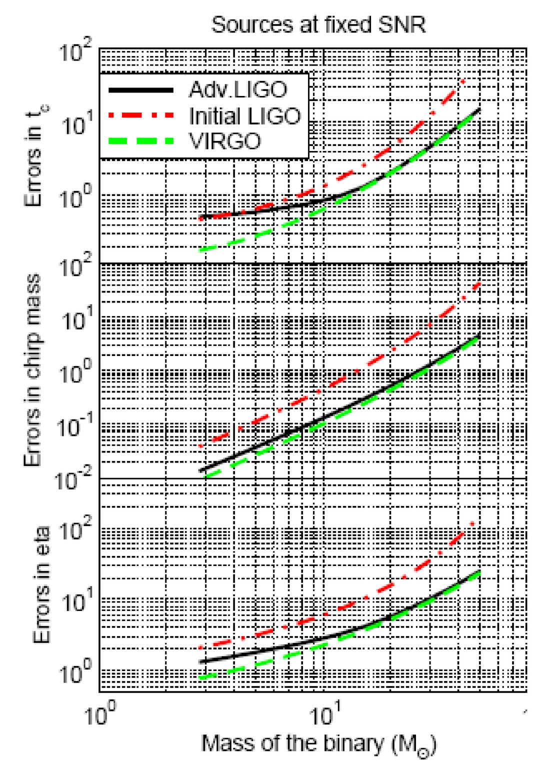
Advantages in glitchy data

Software signal injection studies in glitchy data show that both the injection & glitch ring triggers at the same time

It can so happen that the glitch triggers are louder than the injection.

TrigScan is able to resolve them as different clusters

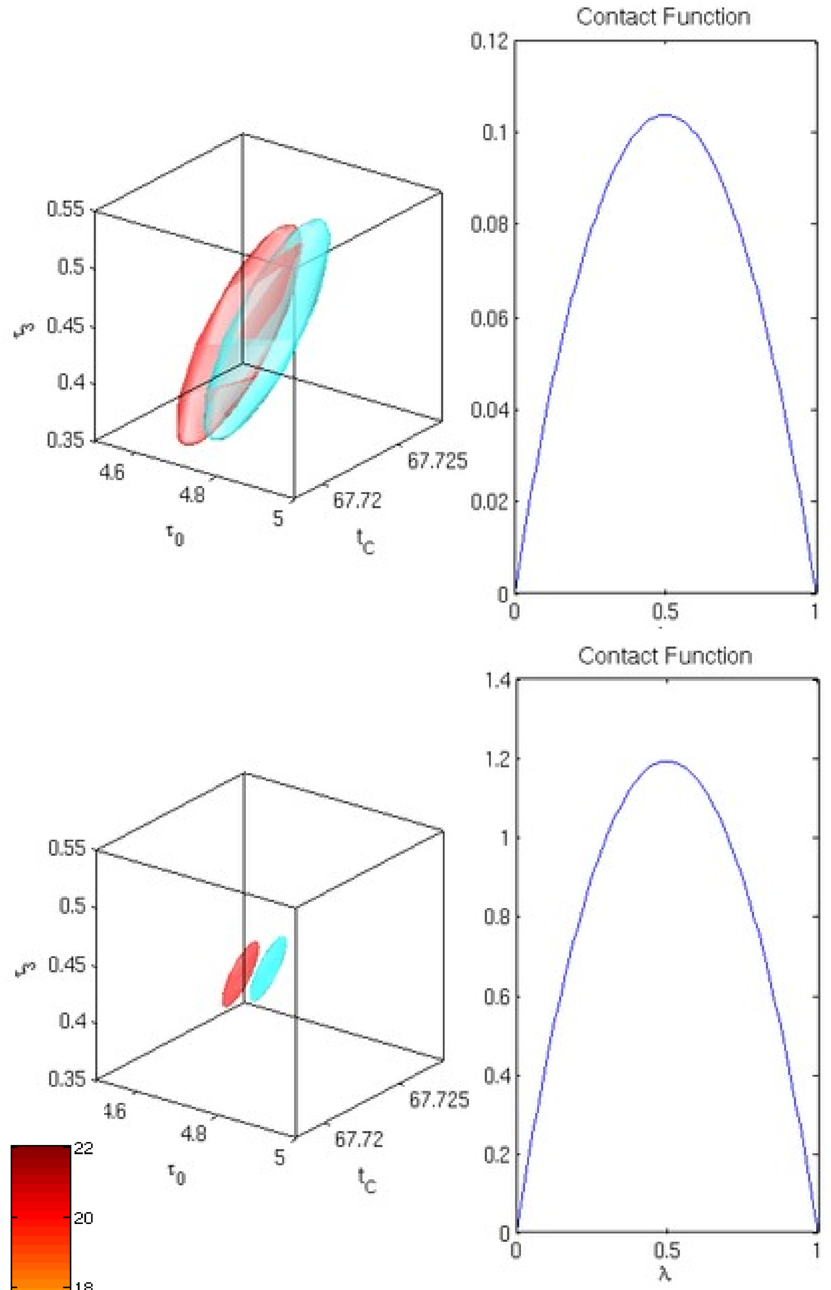




The accuracy of measurement of the parameters of a signal is dependent on the parameters themselves. Naïve coincidence-finding algorithms, which do not take parameter-dependence into account, may result in unnecessarily high false alarm rates in regions of good accuracy; and conversely, a reduction in efficiency in regions of poor accuracy.

K.G. Arun, B. R Iyer, B.S. Sathyaprakash, P.R. Sundararajan, 2004

The efficacy of the ellipsoidal coincidence algorithm has been tried on LIGO data. Preliminary results have shown that this method can help decrease background triggers by an order of magnitude whereas not affecting the injection efficiency to any appreciable degree.



Overlap of ellipsoids

Both the clustering as well as coincidence finding algorithms depend on the test of overlaps of ellipsoids. This test is carried out by constructing and maximizing a Perram and Wertheim contact function $\mathcal{F}_{ij}(\lambda)$.

This function depends on a single scalar parameter bound between 0 and 1. If the maxima of the contact function is less than 1, then the ellipsoids overlap as shown in the figure.

E-Thinca: A simple coincidence finding algorithm for inspiral pipeline

Coincidence windows are now replaced by error ellipsoids associated with each trigger. The size and orientation of ellipsoids are determined by the metric (shape parameter).

The biggest advantage is the reduction in the number of tunable parameters to 1 : in the traditional method one had to tune individual windows over coincidence parameters. In the ellipsoidal coincidence method, one tunes the shape matrix scaling factor.

A further advantage in this method lies in the fact that it naturally introduces parameter dependence, as the eigenvalues of the shape matrix depends where it is evaluated in the parameter space.

By using the information about correlation, we are able to choose the right orientation of the ellipsoids – hence the coincidence finding by the method of overlaps is much more efficient. This can easily seen by comparing the volume of the ellipsoid and the enclosing cuboid.

Coincidence algorithm	Number of Background Triggers	Percentage of "found" injections
Traditional (Cuboid overlap)	39952	45.87%
E-Thinca (Ellipsoid overlap)	3896	45.61%

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