Triggered Search for Gravitational Waves

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Example: Detecting GW bursts associated with GRBs

Some problems:

1. Due to uncertainties in GRB progenitors and the violent nature of the event, GWBs waveform will not be known a priori.

2. Since GRBs are cosmological, the SNR of a single GWB will be too small for a high confidence detection.

However:

1. If GRBs are accompanied by GWBs, the correlated output of two GW detectors at the time of the GRBs (on-source) will differ from the correlated output at other times (off-source).

2. A statistically significant difference between on- and off-source correlations supports a GWB/GRB association and represents a detection of the GWB.

3. Can test for this difference using Student's t-test (which does not require knowledge of the GWB waveform, source distribution, or detailed knowledge of the detector noise).

Student's t-test

"Do two distributions, Y_{on} and Y_{off}, whose variances are equal, have the same mean?"

$$t = \frac{\overline{Y_{\mathrm{on}}} - \overline{Y_{\mathrm{off}}}}{s_D}$$

where

$\overline{Y_{\mathrm{on}}} = \frac{1}{N}\sum_{i=1}^{N} Y_{\mathrm{on}i}$ is sample mean of Y_{on}

$\overline{Y_{\mathrm{off}}} = \frac{1}{N}\sum_{i=1}^{N} Y_{\mathrm{off}i}$ is the sample mean of Y_{off}

$s_D = \sqrt{\frac{s_{\mathrm{on}}^2}{N} + \frac{s_{\mathrm{off}}^2}{N}}$ is the standard error

$s_{\mathrm{on}}^2 = \frac{1}{N-1}\sum_{i=1}^{N}(Y_{\mathrm{on}i} - \overline{Y_{\mathrm{on}}})^2$ is the sample variance of Y_{on}

$s_{\mathrm{off}}^2 = \frac{1}{N-1}\sum_{i=1}^{N}(Y_{\mathrm{off}i} - \overline{Y_{\mathrm{off}}})^2$ is the sample variance of Y_{off}

Cross-correlation statistic:

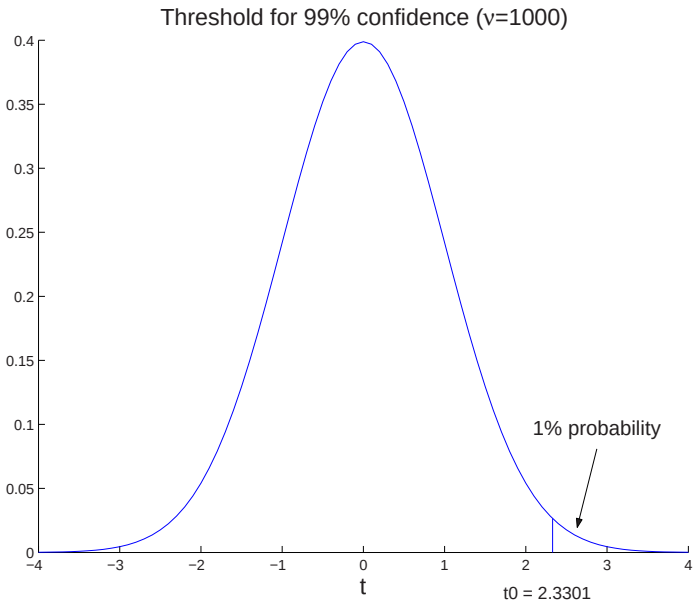
$$Y = \int_0^T dt \int_0^T dt'\, x_1(t_1^\gamma - t)\, Q(|t - t'|)\, x_2(t_2^\gamma - t')$$

T is the time interval between start of GWB and arrival of GRB.

Student's t-test (cont.)

1. Pose the null hypothesis H_0: $p_{\text{on}}(Y) = p_{\text{off}}(Y)$.

2. Determine t_0 for which, when H_0 is true, $t > t_0$ in less than e.g., 1% of all observations.



3. The test:

   (a) If $t > t_0$, reject null hypothesis and conclude we detected a GWB/GRB association with significance 99%.

   (b) If $t \leq t_0$, accept null hypothesis and conclude the data is consistent with no GWB/GRB association.

Upper limit on SNR of GWBs associated with GRBs

	$N = 10$	$N = 100$	$N = 500$	$N = 1000$
90%	0.595	0.182	0.0811	0.0573
95%	0.775	0.234	0.104	0.0736
99%	1.14	0.332	0.147	0.104
99.99%	2.08	0.536	0.236	0.167