

Stochastic Background Code in LAL and LALWrapper

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Underlying Mathematics

- Optimally Filtered Cross-Correlation Statistic

$$\begin{aligned} Y &= \int dt_1 \int dt_2 h_1(t_1) Q(t_1 - t_2) h_2(t_2) \\ &= \int df \tilde{h}_1(f)^* \tilde{Q}(f) \tilde{h}_2(f) \end{aligned}$$

- Optimal filter

$$\tilde{Q}(f) \propto \frac{\Omega_{\text{GW}}(f) \gamma(f)}{f^3 P_1(f) P_2(f)}$$

- For Upper Limits run, look for $\Omega_{\text{GW}}(f) = \text{constant}$

Effect of Response Function

- Response function $\tilde{R}(f)$ relates “whitened” data stream $\tilde{h}_{1,2}^W(f) = \tilde{R}_{1,2}(f) \tilde{h}_{1,2}(f)$ to GW strain $\tilde{h}_{1,2}(f)$

- Calculate CC statistic

$$Y = \int df \tilde{h}_1^W(f)^* \tilde{Q}^W(f) \tilde{h}_2^W(f)$$

using “Whitened” optimal filter

$$\tilde{Q}^W(f) \propto \left(\frac{\tilde{R}_1(f)}{P_1^W(f)} \right)^* \frac{\gamma(f) \Omega_{\text{GW}}(f)}{f^3} \left(\frac{\tilde{R}_2(f)}{P_2^W(f)} \right)$$

LAL Data Analysis Routines

- **Routines to Simulate Data:**

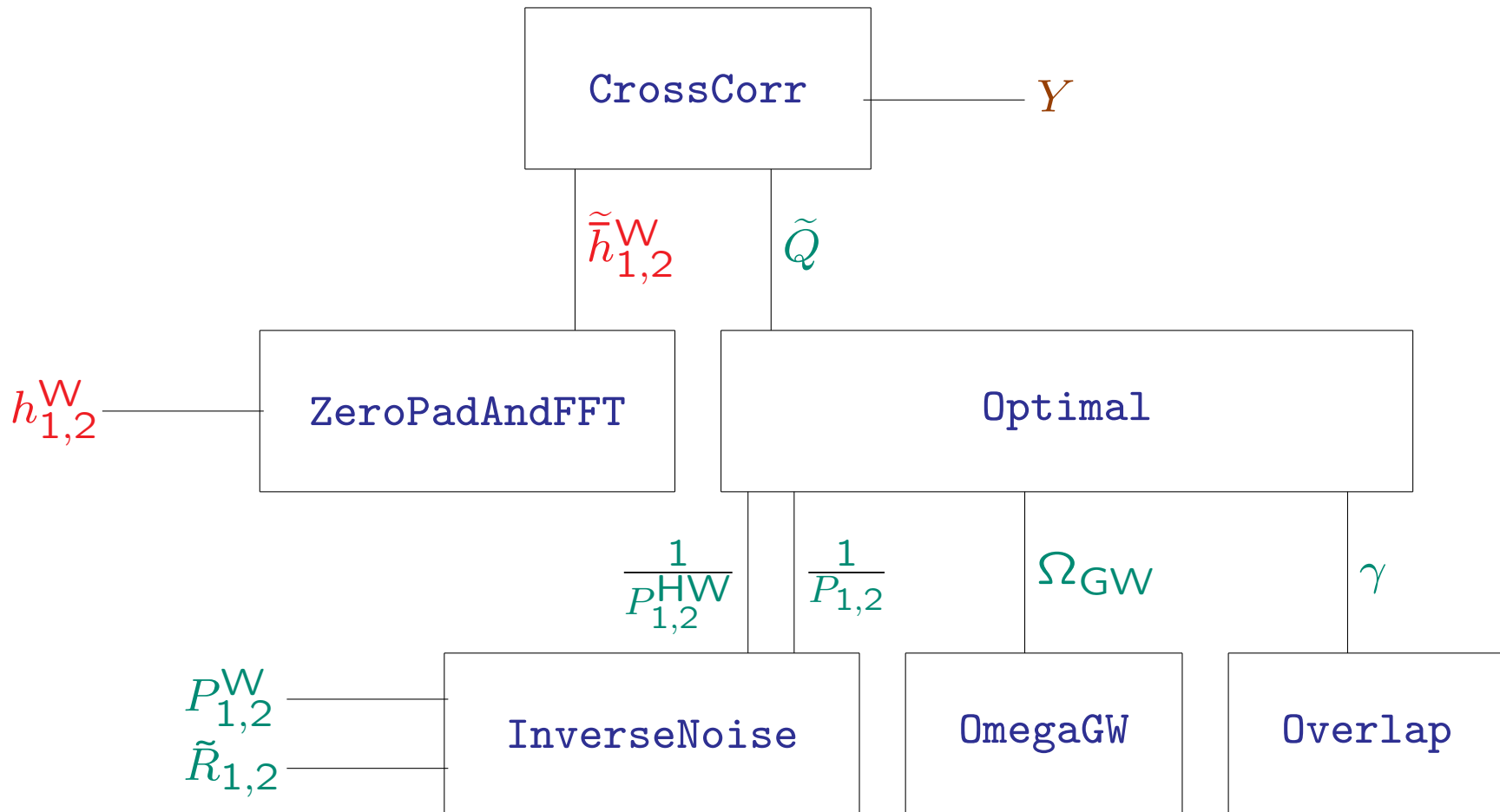
Written by Sukanta Bose & Bruce Allen;
part of `inject` package

- **Routines to Calculate Cross-Correlation Statistic:**

Written by UTB group; LAL package `stochastic`

Existing code available from LAL CVS

Calculating CC Stat: Data Pipeline



Recently Added Functionality

- `CoarseGrainFrequencySeries.c`:
New module: **Lowers resolution** when desired, while keeping integrated value the same
- `ZeroPadAndFFT.c`:
Now works on **real** (non-hetero) or **complex** (heterodyned) time series
- `StochasticCrossCorrelation.c`:
Now calc **real** (non-hetero) or **complex** (hetero) CC stat
Can also calculate CC **spectrum** \equiv integrand

$$Y(f) = \tilde{h}_1(f)^* \tilde{Q}(f) \tilde{h}_2(f)$$

Search Engines: `lalwrapper` Shared Objects

Two Search Engines:

- Contrib DSO `stochastic` (UTB Group): Designed for **IFO-IFO** correlations; available from LALWrapper CVS
- Contrib DSO `stochastic-bar` (under construction @ LSU): Designed for **IFO-bar** correlations (e.g., LLO-ALLEGRO); Uses new functions `LALCZeroPadAndFFT()` & `LALHeterodynedCrossCorrelationStatistic()` designed for **heterodyned** data.
- May eventually build all functionality into one DSO

Flow of Data in stochastic DSO

1. Data streams (~ 15 min) from two IFOs read from frames; also power spectra from LDAS data conditioning API & response functions from database
2. Data divided into manageable chunks (~ 1 min)
3. Optimal filter constructed (using PSDs, response, & observing geom)
4. Loop through data:
 - (a) Zero pad/FFT chunk from each IFO
 - (b) Apply optimal filter & write CC spectrum/statistic to database or frames

Note: For UL analysis, only one target signal, so all analysis done on one node (search master)

See For Yourself

- LAL `stochastic` package in LAL CVS: (Code freeze **Aug 20**)
Routines in place; testing & documentation being finished
- LALWrapper `stochastic` contrib DSO in LALWrapper CVS:
(Code freeze **Aug 27**)
Complete but not final version; schema file & sample ILWD
in `examples` directory runs w/trivial data in standalone mode;
Same data have also been run through LDAS system at CIT
- MDC **September 4-10** at MIT