Broad-band CW searches  
(for isolated pulsars)  
in LIGO and GEO S2 and S3 data

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What’s new (compared to S1)?

- **S1**: targeted search for a single pulsar J1939+2134
- **S2/S3**: moving towards a hierarchical CW search
  - Expand parameter space (but using coherent techniques)
  - Also developing hierarchical techniques in parallel
- **Two general types of CW search:**
  - Short observation time (~ half-day) all-sky, no spindown parameters, 150-450 Hz
  - Longer observation time, (perhaps) one spin-down parameter, small-area search (Galactic plane, SN remanents). There is a delicate trade-off between sensitivity, observation time (spanned and effective), parameter-space resolution, and source class. We hope to use grid techniques to employ thousands of CPUs for around a month.
- **Note that different choices might need to be made to produce the best upper limits.**
Large-scale CW search
with GriPhyN LIGO

• First attempted for the SuperComputing 2003 meeting last month. S. Koranda is our liason with the computer scientists.
• Entire S2 observation time, 200 Hz band, look at the Galactic Center
• Used approximately 1600 CPUS in the LSC data grid: www.lsc-group.phys.uwm.edu/lscdatagrid/details.html
  » AEI (Merlin, 360 CPUs)
  » Birmingham (Tsunami, 200 CPUs)
  » Cardiff (160 CPUs)
  » Caltech (200 CPUs)
  » Penn State (312 CPUs)
  » UTB (Lobizon, 73 CPUs)
  » UWM (Medusa, 296 CPUs)
• Also accessed some ‘non-LSC’ grid resources
• Still doesn’t work as well as we want: Globus Job Manager has trouble managing $10^5$ or $10^6$ compute jobs
Modifications from S1 code

- Internal loop to search over sky positions and spindown parameters
- More robust $S_h$ estimation technique, using running median code by Mohanty, corrected for bias expected for an exponential distribution as function of window size (Krishnan)
- Use 30-min rather than 1-min SFTs. Need new calibration method (Siemens talk Friday)
Outlier due to large disturbance

- Power spectral density showing a large line near 406 Hz
- Corresponding values of the F statistic, showing the resulting outlier. This outlier corresponds to an ENORMOUS signal-to-noise ratio.
Large Outliers and how to veto them

- Graph shows F-statistic as a function of pulsar $f_0$
- Does not have profile expected from a real signal
- A real signal has a sharp peak, with a narrow width of $< 10$ bins, not this structure
- Itoh has implemented a $\chi^2$ test (next talk) to distinguish these artifacts
Detection/Upper Limits

• We’ll do follow-up studies on significant ‘events’, using multiple IFOs
• Detection very unlikely, in which case we’ll use loudest event methods (as in S1 paper, also see J. Creighton talk, Friday) to set a upper limits
• Without vetos, the loudest event method will give much poorer upper limits
Pipeline including the $\chi^2$ test

ComputeFStatistic
area $\{\alpha, \delta\}$
band $\{f_0\} \sim 0.5f_0$

"cluster finder": threshold $F^*$

$\alpha_{1,21}, \delta_{1,21}, N, \text{mean, std, max}$
$\alpha_{2,52}, \delta_{2,52}, N, \text{mean, std, max}$

Fstat shape test:

ComputeFStatistic + parameter estimation
$\equiv (\alpha_{1,21})$
small band around $f_{01}$
$\sim 0.1 \text{mHz}$

For each event we do this:

estimate of signal parameters and generation of $F(f_0)$

$P(0, \psi, \Phi) + \{E\}$

construct a signal $\chi_0$

chi-square test

LOUDEST EVENT

UPPER LIMIT

ComputeFStatistic

(Fs)
Illustration of $\chi^2$ test (Itoh talk)
Example: Setting Upper Limits

- Use 10h of the best H1 S2 data
- Search 15 x 15 degrees around Galactic Center
- Show maximum 2F value in 0.5 Hz band
- $\chi^2$ test will reduce values further
- Each 2F value gives $h_0^{95\%}$ upper limit via Monte Carlo studies in that band.

262 - 264 Hz
2F (max) = 37.9
$10^6$ Monte Carlo
$h_0 \sim$ several
$10^{-23}$ preliminary